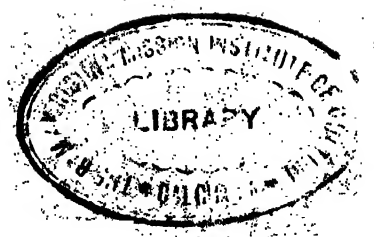


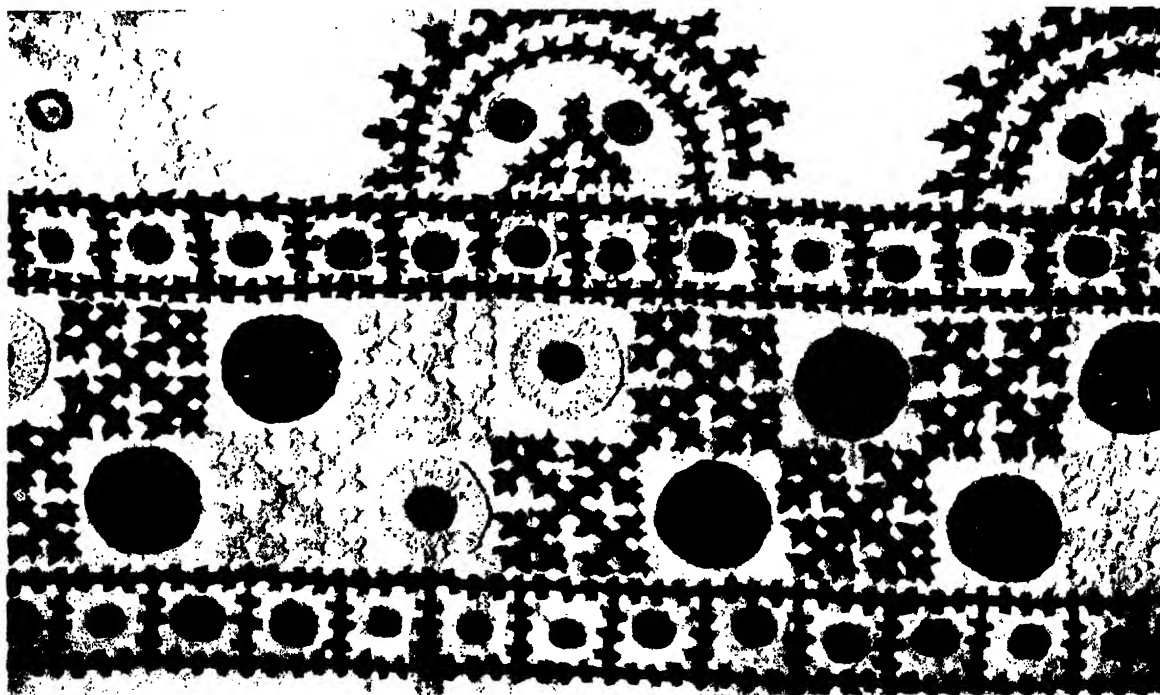
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THE
WEALTH OF INDIA



Kashmir bedcover embroidered in silk *Central Cottage Industries Emporium, New Delhi*



Sindhi mirror-work

Central Cottage Industries Emporium, New Delhi

THE WEALTH OF INDIA

A DICTIONARY OF
INDIAN RAW MATERIALS
AND INDUSTRIAL PRODUCTS

INDUSTRIAL PRODUCTS

PART III : D — E

(*With Index to Parts I - III*)



COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH
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INTRODUCTION

THE present volume comprising articles commencing with the letters D and E follows, in the main, the pattern of the earlier parts of the series. The selection of items dealt with is based on the *Alphabetical Index of the Commodities that enter into the Sea-borne Trade of British India* (Manager of Publications, Delhi, 1938), Brady's *Materials Handbook* (McGraw-Hill Book Co., N.Y., 1947) and *Raw Materials Guide* (H.M.S.O., London). In the treatment of subjects, the directions of the Editorial Committee have been adhered to. An attempt has been made to trace the development of the industries dealt with and to describe their present position; the principal raw materials and their sources and availability are indicated; a description of the manufacturing processes is given and available statistical data are presented.

As pointed out in the introduction to the previous part, the paucity of published information and statistical data on Indian industries and the reluctance on the part of certain industries to supply information, have contributed to the unevenness noticeable in the treatment of the subjects. Such information as has been presented in the articles has been collected mainly through correspondence, personal contacts with manufacturers, and visits to factories. The present volume contains articles dealing with fifty-four industries. Some of them have been grouped together under major heads. Thus thirteen industries, including Radio receivers and components, Telegraph and telephone equipment, Transformers, and Wires and cables, are covered under the subject Electrical industries. Fifteen items, including Lemongrass oil and Sandalwood oil, are dealt with under Essential oils. The volume also includes indices to Parts 1, 2 and 3.

The following articles have been received from external contributors: Dairy industry (Shri C. P. Anantakrishnan and Shri N. N. Dastur), Electric lamps (The *Bengal Electric Lamp Works Ltd.*, Calcutta), Radio receivers and components (Shri S. P. Chakravarty; Shri T. V. Ramamurthy), Sandalwood oil (Shri S. G. Sastry), Linaloe leaf oil (Shri S. G. Sastry), Ethyl acetate (*Alembic Chemical Works Ltd.*, Baroda), and Ethyl chloride (*Alembic Chemical Works Ltd.*, Baroda). These contributions have been modified to conform to the requirements of the Dictionary. Informative notes on the following subjects have been received from external sources: Dairy industry (Milk Commissioner, Government of Bombay; *Polson Ltd.*, Anand; Shri M. D. Parekh), Dehydration (Ministry of Food, New Delhi; Indian Central Coconut Committee, Ernakulam), Denaturants (Chemical Examiner Customs House, Calcutta), Diesel engines (*Cooper Engineering Ltd.*, Satara Road), Disinfectants (*Parry & Co. Ltd.*, Madras; *Bararee Coke Co. Ltd.*, Kusunda, Bihar), Distilled liquors (Mr. W. A. Green; Central Revenue Control Laboratory, New Delhi), Dyestuffs (The Dyestuffs Manufacturers' Association of India, Bombay), Electric carbons (*Indian Aluminium Co. Ltd.*, Alwaye), Electric fans [*Indian Electric Works Ltd.*, Calcutta; *Crompton Parkinson (Works) Ltd.*, Bombay; Fan Makers' Association of India, Calcutta], Electric fittings (*Swadeshi Industries Ltd.*, Calcutta; Lamp Holders Manufacturers' Association, Calcutta; The *National Conduits Ltd.*, Delhi), Electric insulators (*Government Porcelain Factory*, Bangalore), Electric lamps (Indian Lamp Factories' Association, Calcutta; *Radio Lamp Works Ltd.*, Shikohabad), Electric motors [*Crompton Parkinson (Works) Ltd.*, Bombay], Radio receivers and components [*Philips Electrical Co. (India) Ltd.*, Calcutta; The *National Ekco Radio & Engineering Co. Ltd.*, Bombay; The *IRP (Radios) Ltd.*, Calcutta; *Eastern Electronics*, Faridabad; All India Radio, New Delhi; State Broadcasting Department,

Madras], Electric switchgears [*Associated Electrical Industries (India) Ltd.*; Calcutta], Telegraph and telephone equipment (*P. & T. Workshops*, Calcutta; *Indian Telephone Industries Ltd.*, Bangalore; *India Electric Works Ltd.*, Calcutta], Electric transformers [*Crompton Parkinson (Works) Ltd.*, Bombay], Electric wires and cables (*The National Insulated Cables of India Ltd.*, Calcutta; *The Indian Cable Co. Ltd.*, Golmuri, Bihar; *Aluminium Industries Ltd.*, Kundara, Travancore-Cochin), Enamelware (*Sur Enamel & Stamping Works Ltd.*, Calcutta), Essential oils (Shri N. S. Varier; *Mettur Sandalwood Oil Company*, Mettur Dam), Ether (*Bengal Chemical and Pharmaceutical Works Ltd.*, Calcutta), and Explosives (*The Indian Oxygen & Acetylene Co. Ltd.*, Calcutta; Chief Inspector of Explosives in India, New Delhi). The Chief Editor wishes to acknowledge his gratitude to the authors of the articles and notes.

Thanks are due to the following industrial concerns for affording facilities to my colleagues to visit the factories and collect information: *A. K. Sarkar (Industries) Ltd.*, Calcutta; *Associated Electrical Industries (India) Ltd.*, Calcutta; *Bengal Chemical and Pharmaceutical Works Ltd.*, Calcutta; *The Bengal Electric Lamp Works Ltd.*, Calcutta; *Calcutta Electrical Manufacturing Co. Ltd.*, Calcutta; *Calcutta Fan and Motor Manufacturing Co.*, Calcutta; *Electric Construction and Equipment Co. Ltd.*, Calcutta; *Electric Lamps Manufacturers (India) Ltd.*, Calcutta; *Government Electrical Factory*, Bangalore; *Government Porcelain Factory*, Bangalore; *Hindustan Wire & Metal Products Ltd.*, Calcutta; *India Electric Works Ltd.*, Calcutta; *The Indian Cable Co. Ltd.*, Golmuri (Bihar); *Indian Telephone Industries Ltd.*, Bangalore; *The IRP (Radios) Ltd.*, Calcutta; *Mysore Lamp Works Ltd.*, Bangalore; *Kirloskar Electric Co.*, Bangalore; *National Insulated Cables of India Ltd.*, Calcutta; *Parry & Co. Ltd.*, Ranipet (Madras); *Philips Electrical Co. (India) Ltd.*, Calcutta; *P.S.G. & Sons' Charity Industrial Institute*, Coimbatore; *P. & T. Workshops*, Alipore, Calcutta; *Radio & Electricals Ltd.*, Madras; *Radio & Electrical Manufacturing Co. Ltd.*, Bangalore; *Radio Lamp Works Ltd.*, Shikohabad; *Russa Distillery*, Calcutta; *Sandalwood Oil Factory*, Mysore; *Sur Enamel & Stamping Works Ltd.*, Calcutta; and *Sivadeshi Industries Ltd.*, Calcutta.

The Chief Editor wishes to place on record his grateful acknowledgement of the willing cooperation which has been extended to him in the compilation of this work by several institutions, Government Departments, individual scientists and industrialists, both in India and abroad. Many articles have been referred to specialists for scrutiny and opinion, and information has been collected from a large number of sources. It is impossible to thank everyone who has assisted in this work individually. The Chief Editor hesitates to make any special mention as every one whom he approached has been equally responsive.

The Chief Editor desires to express his gratitude to Dr. S. S. Bhatnagar in particular and to each of the other members of the Editorial Committee for help, guidance and criticism. He wishes to place on record his grateful appreciation of the unstinted labour and loyal cooperation of his colleagues and staff.

Thanks are due to the authorities of the United Press, Delhi, for the neat execution of the printing. But for their willing assistance, the printing of this volume would have been difficult.

Suggestions for improvement will be gratefully received and made use of in subsequent volumes.

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(The abbreviations, in general, are those given in the World List of Scientific Periodicals, 1932)

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| <i>Agric. Anim. Husb. U.P.</i> | .. | Agriculture and Animal Husbandry, Uttar Pradesh, Lucknow. |
| <i>Agric. Live-stk. India</i> | .. | Agriculture and Live-Stock in India, Delhi. |
| <i>Allahabad Fmr</i> | .. | Allahabad Farmer, Allahabad. |
| <i>Amer. chem. Soc., News Ed.</i> | .. | American Chemical Society. News Edition. |
| <i>Amer. Rev. Tuberc.</i> | .. | American Review of Tuberculosis, New York. |
| <i>Aust. J. Dairy Tech.</i> | .. | Australian Journal of Dairy Technology, Melbourne. |
| <i>BIOS Final Rep.</i> | .. | Final Report of the British Intelligence Objectives Sub-Committee, London. |
| <i>Bull. Dep. Agric. Bombay</i> | .. | Bulletin, Department of Agriculture, Bombay. |
| <i>Bull. Dep. Industr. Beng.</i> | .. | Bulletin, Department of Industries, Bengal, Calcutta. |
| <i>Bull. Dep. Industr. Comm. U.P.</i> | .. | Bulletin of the Department of Industries & Commerce, U.P. (New Series), Allahabad. |
| <i>Bull. imp. Inst., Lond.</i> | .. | Bulletin of the Imperial Institute, London. |
| <i>Bull. U.P. For. Dep.</i> | .. | Bulletin, United Provinces Forestry Department, Allahabad. |
| <i>Ceylon Yearb.</i> | .. | Ceylon Yearbook Colombo. |
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| <i>Chemical Age, Bombay</i> | .. | Chemical Age, Bombay. |
| <i>Chemical Age, Lond.</i> | .. | Chemical Age, London. |
| <i>Chem. Engng</i> | .. | Chemical Engineering, New York. |
| <i>Chem. & Drugg.</i> | .. | Chemist and Druggist, London. |
| <i>Chemurg. Dig.</i> | .. | Chemurgic Digest, Columbus, Ohio. |
| <i>Circ. U.S. Dep. Agric., Fd Drug Adm.</i> | .. | Circular, United States Department of Agriculture, Food & Drug Administration, Washington. |
| <i>Comm. & Industr.</i> | .. | Commerce & Industry, New Delhi. |
| <i>Curr. Sci.</i> | .. | Current Science, Bangalore. |
| <i>Eastern Economist</i> | .. | Eastern Economist, New Delhi. |
| <i>Econ. Bot.</i> | .. | Economic Botany, Lancaster, Pa. |
| <i>Food Ind.</i> | .. | Food Industries, New York. |
| <i>FIAT Final Rep.</i> | .. | Final Report of the Field Information Agency - Technical, British Intelligence Objectives Sub-Committee, London. |
| <i>I. & S. Bull.</i> | .. | I. & S. Bulletin, New Delhi. |
| <i>Indian Cocon. J.</i> | .. | Indian Coconut Journal, Ernakulam. |
| <i>Indian east. Engr</i> | .. | Indian and Eastern Engineer, Calcutta. |
| <i>Indian For. Bull.</i> | .. | Indian Forest Bulletin (New Series), Delhi |
| <i>Indian For. Leaf.</i> | .. | Indian Forest Leaflets, Dehra Dun. |
| <i>Indian For. Rec.</i> | .. | Indian Forest Records, Delhi. |
| <i>Indian J. Pharm.</i> | .. | Indian Journal of Pharmacy, Banaras. |
| <i>Indian Soap J.</i> | .. | Indian Soap Journal, Calcutta. |
| <i>Indian Tr. J.</i> | .. | Indian Trade Journal, Delhi. |
| <i>Industry</i> | .. | Industry, Calcutta. |
| <i>Industr. Engng Chem.</i> | .. | Industrial and Engineering Chemistry, Easton, Pa. |
| <i>Industr. Engng Chem., Anal. Ed.</i> | .. | Industrial and Engineering Chemistry (Analytical Edition), Easton, Pa. |
| <i>J. Amer. ceram. Soc.</i> | .. | Journal of the American Ceramic Society, Easton, Pa. |
| <i>J. Amer. med. Ass.</i> | .. | Journal of the American Medical Association, Chicago. |
| <i>J. Dairy Sci.</i> | .. | Journal of Dairy Science, Baltimore, Lancaster, Pa. |
| <i>J. Indian chem. Soc.</i> | .. | Journal of the Indian Chemical Society, Calcutta. |
| <i>J. Indian chem. Soc. Industr. Edn</i> | .. | Journal of the Indian Chemical Society, Industrial Edition, Calcutta. |

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|---|----|---|
| <i>J. Indian chem. Soc. Industr. & News Edn</i> | .. | Journal of the Indian Chemical Society, Industrial and News Edition, Calcutta. |
| <i>J. Indian Ind.</i> | .. | Journal of Indian Industries and Labour, Calcutta. |
| <i>J. Indian Inst. Sci.</i> | .. | Journal of the Indian Institute of Science, Bangalore. |
| <i>J. Instn elect. Engrs</i> | .. | Journal of the Institution of Electrical Engineers, London. |
| <i>J. sci. industr. Res.</i> | .. | Journal of Scientific & Industrial Research, New Delhi. |
| <i>J. Soc. chem. Ind. Lond.</i> | .. | Journal of the Society of Chemical Industry, London. |
| <i>J. Soc. Dy. Col.</i> | .. | Journal of the Society of Dyers and Colourists, Bradford. |
| <i>Madras agric. J.</i> | .. | Madras Agricultural Journal, Madras |
| <i>Misc. Bull. I.C.A.R.</i> | .. | Miscellaneous Bulletins, Indian (Imperial) Council of Agricultural Research, Delhi. |
| <i>Misc. Publ. U.S. Dep. Agric.</i> | .. | Miscellaneous Publications, United States Department of Agriculture, Washington. |
| <i>Perfum. essent. Oil Rev.</i> | .. | Perfumery and Essential Oil Record, London. |
| <i>Philips tech. Rev.</i> | .. | Philips Technical Review, Eindhoven. |
| <i>Proc. Porcel. Enam. Inst.</i> | .. | Proceedings of the Porcelain Enamel Institute, Chicago. |
| <i>Quart. J. Indian Inst. Sci.</i> | .. | Quarterly Journal of the Indian Institute of Science, Bangalore. |
| <i>Rep. Progr. appl. Chem.</i> | .. | Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry, London. |
| <i>Schimmel Rep.</i> | .. | Schimmel Report, New York. |
| <i>Sci. & Cult.</i> | .. | Science and Culture, Calcutta. |
| <i>Soap. N.Y.</i> | .. | Soap (and Sanitary Chemicals), New York. |
| <i>Steel</i> | .. | Steel, Cleveland. |
| <i>Times Rev. Ind.</i> | .. | Times Review of Industry, London. |
| <i>Trans. electrochem. Soc.</i> | .. | Transactions of the Electrochemical Society, New York. |
| <i>Tr. U.K.</i> | .. | Annual Statement of the Trade of the United Kingdom with British countries and Foreign countries, London. |
| <i>U.S. Exports of Domestic & Foreign Merchandise</i> | .. | United States Exports of Domestic & Foreign Merchandise, Washington. |
| <i>World Crops</i> | .. | World Crops, London. |
| <i>Yearb. Dep. Agric., Madras</i> | .. | Yearbook Department of Agriculture, Madras. |

**INDUSTRIAL
PRODUCTS
PART : III D—E**

D

DAIRY INDUSTRY

The dairy industry, covering the production, processing and distribution of milk and milk products, is unique in its importance as it is concerned with valuable foodstuffs universally consumed by man.

Milk is the fresh lacteal secretion of milch animals naturally intended for the nourishment of the offspring, but exploited as an article of food by the human race. It is essentially an emulsion of fat in a continuous phase. The disperse phase consists of fat globules of varying diameter from 0.1μ to 10μ (av., $2.5-3.0\mu$). The number of globules varies from 2.5×10^9 to 5×10^9 per cc. The globules are surrounded by layers of protein, phosphatides, and probably also carotene and cholesterol, which prevent them from coalescing together to larger globules. The protective film may be broken by churning the milk when the fat globules coalesce to form butter. Milk fat or butter consists of glycerides mainly of butyric, caproic, and capric acids which possess characteristic odours.

The continuous aqueous phase consists of carbohydrates (almost entirely lactose) and a colloidal suspension of casein stabilized by lactalbumin and lacto-globulin; minor amounts of other nitrogenous constituents and inorganic salts, some of them in colloidal association with casein, are present. Lactose forms the largest single constituent of cow's milk, next only to water. Cow milk contains 2.4-6.1% lactose. The casein can be separated from the milk by treatment with rennet or an acid. Lactalbumin (c. 0.5%) and lacto-globulin (c. 0.05%) remain in solution and can be separated from the whey after the casein is precipitated and removed. In addition to the proteins mentioned, milk contains traces of other proteins and phosphatides in association with fat globules together with secondary proteins of a proteose-peptone nature and residual nitrogenous bodies, such as amino acids, phosphatides, purine bases, urea, and ammonia (Thorpe, VIII, 101).

Milk also contains 'native' enzymes (those present in the udder) and enzymes originating from bacterial contamination. Amylase, catalase, peroxidase, lipase, phosphatase, galactase, lactase, and aldehydase are among the enzymes present in milk (Jacob, II, 847).

The activity of most enzymes present in milk is destroyed or greatly reduced by pasteurization. During pasteurization the most resistant of the pathogenic bacteria present in milk are completely destroyed before the phosphatase and

hence the determination of phosphatase activity provides a method of testing the efficiency of the pasteurization process (Thorpe, VIII, 108). Table 1 gives the constituents of milk.

The white appearance of milk in reflected light and its opacity in transmitted light are due to the emulsified fat and the colloidal calcium phosphate and caseinate. The creamy colour is due to the presence of carotene in the disperse phase and of riboflavin in the aqueous phase.

The recorded values of the physical constants of milk are as follows: sp. gr.^{15°}, 1.028-1.034 (av., 1.032); n_D , 1.3415-1.3423 (av., 1.3420); electrical conductivity, 38.0×10^{-4} - 68.4×10^{-4} mhos (usually, 41×10^{-4} - 50×10^{-4} mhos); $\eta^{15°}$, 0.021-0.026 poises; surface tension, 46.5-53.3 dynes/cm. (usually, 49-52 dynes/cm.); osm. pressure, 6.78 atm.; pH, 6.4-6.9 (av., 6.6) (Thorpe, VIII, 106).

Flavour—The flavour of natural milk is pleasant and slightly sweet. Milk which is rich in lactose possesses a better flavour than that relatively poor in lactose. Milk containing 3-5% fat has a better flavour than milk richer in fat.

The feed given to milking cows influences the flavour of milk. The sour or acid taste of milk

TABLE 1—CONSTITUENTS OF MILK *

| | |
|--------------------|--|
| Lipid | Mixed triglycerides of oleic, palmitic, myristic, stearic, butyric, caproic, caprylic, lauric, capric, decenoic, tetradecenoic, hexadecenoic, and arachidonic acids; fat-soluble vitamins, cholesterol, xanthophyll, phospholipids, cephalin, and lecithin |
| Protein | Casein, lactalbumin, and lactoglobulin; these proteins contain some 20 or more amino acids including all the essential ones |
| Carbohydrate | Lactose |
| Minerals | Sodium, potassium, calcium, phosphorus, chlorine, and sulphur in substantial quantities; magnesium, copper, iron, zinc, manganese, and iodine in smaller amounts; carbonates also present |
| Vitamins | Vitamin A and carotene, vitamins D and E, ascorbic acid, thiamine, riboflavin, niacin, pantothenic acid, and pyridoxine |
| Enzymes | Phosphatase, amylase, lipase, catalase, peroxidase, galactase, and reductase |
| Other constituents | Citric and lactic acids, creatine, creatinine, urea, choline, carbon dioxide, oxygen, nitrogen, and water |

* Jacobs, II, 844

DAIRY INDUSTRY

is due to the activity of lactic acid bacteria and, sometimes, of the coliform group of organisms. Proteolytic organisms decompose milk proteins and impart a bitter flavour. The rancid flavour, sometimes observed in raw milk, is due to the action of lipolytic bacteria. Pasteurization prevents the development of rancidity due to bacterial origin, but does not remove the rancid flavour if already present. Rancidity present sometimes in fresh milk from healthy cows is due to the liberation of fatty acids from the milk fat through the action of lipase present in the milk.

Off-flavours, sometimes observed in heated milk, are due to partially oxidized compounds, primarily oxidized phospholipids. The reactions which bring about these changes are intimately associated with the oxidation and reduction of ascorbic acid. The off-flavours may be prevented either by completely destroying the natural ascorbic acid present in the milk (by the addition of oxidizing agents like hydrogen peroxide) or by preventing the formation of partially oxidized compounds by adding anti-oxidants, such as ascorbic acid. The latter treatment is preferred as it raises the nutritive value of milk.

Nutritive value—Milk is a complete food for infants up to 6 months of age, after which it acts as a supplement to other foods. Cow milk is easily digested. One pint of milk supplies about 320 cal. of which c. 50% is contributed by fat, 20% by lactose, and 21% by protein. Milk is a valuable source of phosphorus, calcium, and vitamins.

Milk is rich in vitamin A, its amount being influenced by the feed of the cow. It is an excellent source of vitamin B₂ (which is rapidly destroyed on exposure to light) and a fair source of vitamin B₁. It is deficient in vitamin C. Milk has a low vitamin D content but it may be increased by irradiation or by feeding milch cows with a diet rich in vitamin D, e.g. irradiated yeast (Thorpe, VIII, 110).

Due to its exceptionally high nutritive value and fluid nature, milk is an ideal medium for the growth of bacteria and it is of prime importance that handling and processing of milk should be carried out under strictly hygienic conditions. Milk contains bacterial flora normally associated with the udder and those introduced during milking and handling operations. All contamination should be effectively removed. Elimination of unhealthy cattle from dairy herds, employment of sanitary conditions for milking, cooling of milk after drawing, pasteurization, and use of sterilized containers for distributing milk are essential measures which should be adopted for ensuring safe milk for consumers. Bacteriological testing, including direct microscopic count, plate count, coliform count, Breedsmeat test, and

methylene blue (or Resazurin) reduction, is necessary to ensure that the product supplied to consumers is safe and wholesome (Thorpe, VIII, 111).

MILCH CATTLE—CARE AND MANAGEMENT

The number of milch cows and buffaloes in the Indian Union is, according to the 1947-48 census, 39,397,000 and 17,634,000 respectively (Table 2), constituting almost one-third of the total cattle population of the country. Of the milch stock only about 5% is found in urban areas. Dairying is predominantly a rural industry.

Cows and she-buffaloes constitute the chief sources of milk supply in India; goats contribute a small amount. Other animals, e.g. sheep, camels, asses, and mares are milked in certain localities but as producers of milk they are of little importance. The total value of milk annually produced in India is estimated to be about Rs. 600 crores.

TABLE 2—POPULATION OF COWS, SHE-BUFFALOES, AND GOATS IN INDIA *

| | Cows† | She-buffaloes‡ | Goats‡ |
|-------------------|------------|----------------|------------|
| Assam | 1,287,435" | 185,046" | 721,781" |
| Bihar | 2,956,413 | 1,173,123 | 2,154,131 |
| Bombay | 2,585,497 | 2,043,167 | 958,724 |
| Madhya Pradesh | 3,927,856" | 816,156" | 2,023,599" |
| Madras | 5,095,825 | 2,943,654 | 3,699,823 |
| Orissa | 2,560,918 | 271,957 | 933,267 |
| Punjab | 12,862 | 6,276 | 6,399 |
| Uttar Pradesh | 5,493,050 | 4,544,932 | 3,335,586 |
| West Bengal | 2,918,085 | 138,384 | 1,264,984 |
| Hyderabad | 2,666,995" | 1,109,582" | 3,387,138" |
| Jammu & Kashmir | 724,967 | 360,078 | 758,006 |
| Madhya Bharat | 1,738,297 | 917,548 | 796,394 |
| Mysore | 1,447,346 | 560,666 | 759,861 |
| PEPSU | 370,111 | 402,106 | 372,595 |
| Rajasthan | 2,968,807 | 1,364,600 | 4,334,031 |
| Saurashtra | 94,947 | 61,686 | 138,488 |
| Travancore-Cochin | 469,658 | 34,117 | 51,598 |
| Ajmer | 97,013 | 41,497 | 146,679 |
| Bhopal | 226,207" | 88,358" | 45,491" |
| Bilaspur | 13,535 | 26,745 | 17,603 |
| Coorg | 39,300 | 7,051 | 943 |
| Delhi | 28,406 | 39,086 | 26,179 |
| Himachal Pradesh | 346,282 | 98,729 | 326,704 |
| Kutch | 83,260 | 34,665 | 206,708 |
| Manipur | 28,216 | 4,817 | 2,924 |
| Tripura | 44,788 | 8,928 | 20,411 |
| Vindhya Pradesh | 171,193 | 351,200 | 400,988 |
| Total | 39,397,289 | 17,634,154 | 26,891,035 |

* Indian Live-stock Statistics, 1947-48 to 1949-50, Econ. & Statist. Adviser, Minist. Agric., New Delhi, 1952, 5, 9, 14, 23, 27 & 32

† Over 3 years kept for breeding or milk production

‡ Over 1 year * Total over 3 years † Total goats over 1 year

Though colossal in magnitude, dairying is a cottage industry subsidiary to agriculture. The bulk of milk is produced in rural areas. The farmer maintains one or more cows and sells the milk to obtain small cash for his needs. The total number of farmer producers in the Indian Union is estimated to be 193 lakhs and the number of milch animals maintained by them, 579 lakhs. Urban producers maintain large herds; the total number of animals in urban areas is estimated to be 13.3 lakh cows and 8.7 lakh buffaloes. On the basis of an average of 10 animals per producer, the number of producers in urban areas is about 2 lakhs.

There are in India about 75 dairy farms, each with a dairy and a herd of about 75 milch cattle. Of these, about a dozen are privately owned; the rest are Government farms. Dairy farming has been an unremunerative enterprise in India on account of the high capital and overhead costs incommensurate with the sale price of milk in most areas.

The number of military dairy farms (including branch farms and issue & milk purchasing depots) in undivided India, during World War II, was about 100. The total strength of herds in the farms was 12,869 heads in 1940 and 65,637 in 1945. At present there are in the Indian Union about 40 military dairy farms (with 30 sub-farms) with a strength of about 15,300 milch cattle. These are permanent establishments primarily maintained

for supplying wholesome milk, butter, and cream to troops and military hospitals.

The farms under civil departments are either attached to educational and research institutions or used as "seed-farms" for raising pedigree bulls for distribution in villages. Milk production and supply form a necessary part of the work of the farms.

A few private dairy farms have been established in the suburbs (within 20 miles radius) of large cities and towns, for supplying milk to urban consumers. The sizes of the farms vary, some maintaining as many as 100 milch animals, others as few as 10. The animals which dry off are sold and newly calved ones purchased to keep up the milk production. In a few farms pasteurization equipment has been installed and milk is delivered to consumers within 2 hours after milking.

Table 3 gives the number of cattle breeding and dairy farms in India.

The largest dairy farm in India is located in Bombay and is sponsored by the State Government. Prior to its establishment, the Government experimented with a subsidized milk distribution scheme, which was in operation during the period August 1944—March 1947. The present scheme was introduced as a long term measure. The village of Aarey (1,100 acres), about 20 miles north of the city, was acquired together with unclaimed adjoining waste land. Producers of

TABLE 3—NUMBER OF CATTLE BREEDING AND DAIRY FARMS IN INDIA *

| | No. of farms | | | | No. of cattle | | | | |
|------------------|--------------|-------|----------------------------|--------------------------------|---------------|-----------|-------------|-------|----------|
| | Breeding | Dairy | Breeding & milk production | Total area of the farm (acres) | Cows | Buffaloes | Young stock | Bulls | Bullocks |
| Bhopal | 1 | .. | .. | 48 | 14 | .. | 12 | 2 | .. |
| Bihar | 1 | 2 | 12 | 4,434 ⁺⁺ | 1,091 | 1,570 | 1,693 | 325 | 522 |
| Coorg | .. | .. | 9 | n.a. | 65 | 36 | 202 | 6 | 126 |
| Delhi | .. | .. | 3 | 290 | 364 | .. | 455 | 8 | 43 |
| Punjab (1) | 1 | 10 | 1 | 40,374 | 3,083 | 77 | 6,520 | 72 | 470 |
| Himachal Pradesh | .. | 1 | 1 | 504 | 44 | 24 | 43 | 3 | 8 |
| Madras | .. | .. | 3 | 2,180 | 455 | 110 | 1,029 | 50 | 116 |
| Orissa | 1 | .. | 7 | 567 | 178 | 28 | 393 | 37 | 77 |
| Uttar Pradesh | 1 | .. | 4 | 10,107 | 460 | 243 | 472 | 377 | 248 |
| Cochin | .. | .. | 4 | 384 | 324 | 13 | 353 | 31 | 28 |
| Kashmir | .. | .. | 1 | 41 | 23 | .. | 35 | 5 | 3 |
| Mysore | 3 | .. | .. | 27,754 | 524 | .. | 893 | 118 | 144 |
| Travancore | .. | 2 | 3 | 204 | 174 | 21 | 138 | 7 | 3 |
| Madhya Bharat | 3 | .. | 5 | 1,120 ^m | 144 | 50 | 259 | 21 | 75 |
| PEPSU | .. | 1 | .. | 324 | 40 | 88 | 114 | 5 | 12 |
| Rajasthan† | 2 | 2 | 2 | n.a. | 60,060 | 50 | 99,032 | 1,909 | 2,064 |
| IDRI‡, Bangalore | .. | .. | 1 | 202 | 234 | 27 | 221 | 16 | 31 |

* Live-stock Statistics, Econ. & Statist. Adviser, Minist. Agric., New Delhi, 1950, 50

** plus 1,200 bighas @ plus 561 bighas

n.a. Not available † Relates to Jaipur and Jodhpur states only

‡ Indian Dairy Research Institute

DAIRY INDUSTRY

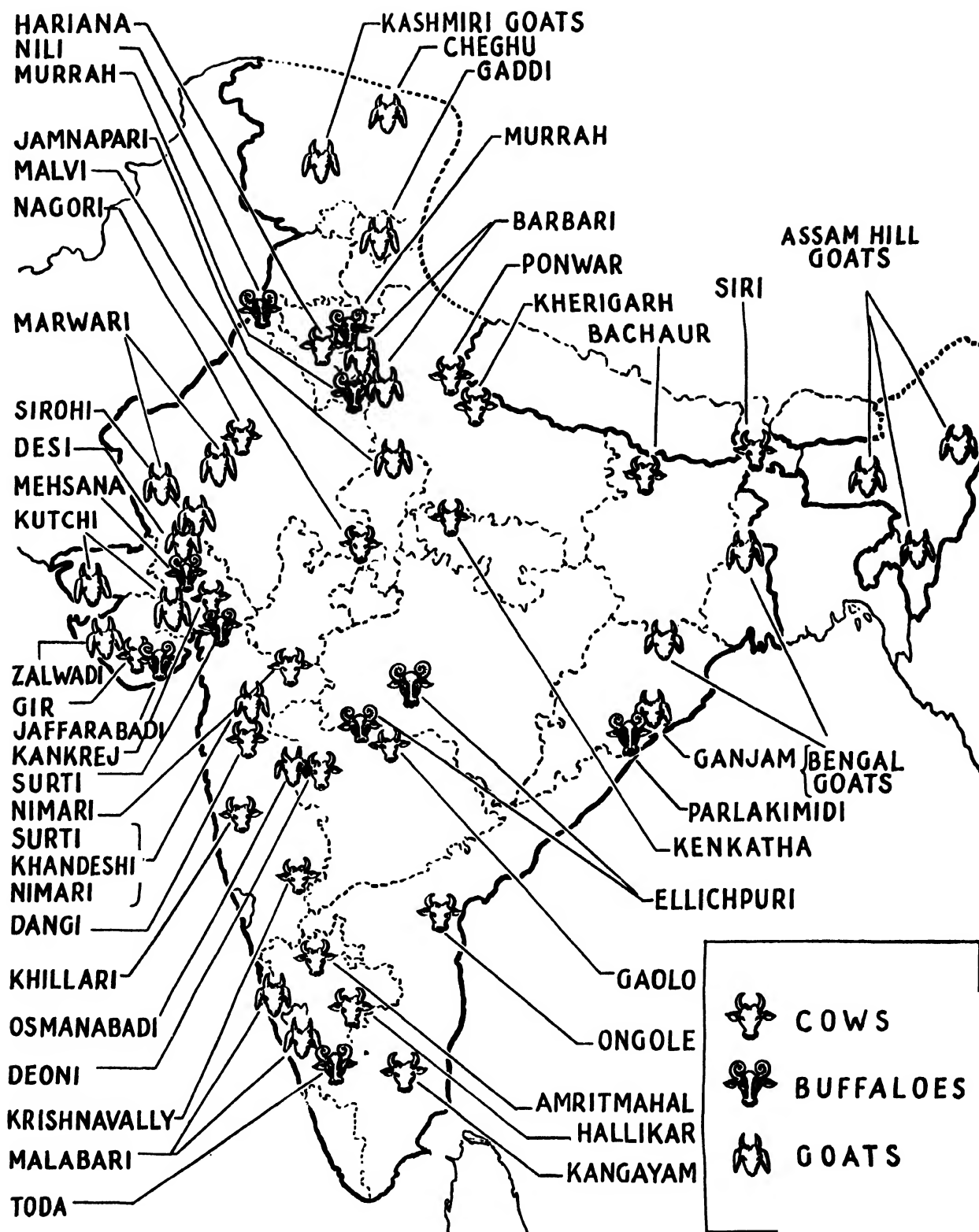


FIG. 1—DISTRIBUTION OF DIFFERENT BREEDS OF COWS, BUFFALOES, AND GOATS IN INDIA

milk in urban areas were invited to settle down on farms into which the area was divided. There are now 26 well designed farm units to which all but 2,000 of the 15,000 milch animals previously found in Bombay have been shifted. In addition, milk from some 8,000 buffaloes is brought from Anand to the colony for processing and distribution.

Each farm is provided with sanitary milking sheds, calf-pens, calving lines, bull-pens, grain and hay godowns, and residential accommodation for servants, supervisors, and owners. Each unit accommodates 475 adult cattle in addition to calves. Each farm covers 8 acres and 40-60 acres of agricultural land are attached to it. Cattle feeds and hay are purchased in bulk during the season and supplied to milk suppliers on "no loss, no profit" basis. Manure and wash water are utilized for raising fodder crops. A co-operative bank, an artificial insemination centre, veterinary

dispensaries, and calf rearing units have been established at Aarey.

Cattle Breeds—The number of well recognized cow breeds in India is about 30. In addition, a large number of types which do not conform to any definite breed characteristics exist and are treated as non-descripts. The animals are used both for milk supply and draught purposes. The non-descripts are poor producers of milk, but as the animals can be maintained at little cost in rural areas, they are also used for obtaining milk. Table 4 gives the distribution of recognized cow breeds in India.

The buffalo is generally regarded as the dairy animal of India. There are 6 breeds of buffaloes of which 5 are used for milk production. There are also non-descripts. Table 5 gives some of the well known breeds of buffaloes used for milk production.

TABLE 4—PRINCIPAL BREEDS OF COWS *

| Breed | Locality | Remarks |
|----------|--|---|
| Deoni | North-western and western parts of Hyderabad | Best milkers in Hyderabad |
| Gaolao | Wardha and Chindwara districts of Madhya Pradesh | Moderate milkers |
| Gir | Kathiawar; also Rajputana, Baroda, and northern Bombay; Halar in Wankaner; Chotilla Hills of Morvi state | Good milkers; 3,500 lb. (farm average) per lactation |
| Hariana | Rohtak, Hissar, Karnal and Gurgaon districts of Punjab, Delhi, and a wide area to the south of these districts, particularly in west U.P., Alwar and Bharatpur | Good milkers; c. 3,500 lb. (up to 6,700 lb. in farms) per lactation |
| Kankrej | South-east of Rann of Kutch, extending from the south-west corner of Tharparker district of Sind to Ahmedabad district, and from Deesa in the east to Radhanpur in the west, particularly along the Banas and Saraswati rivers | Fair milkers; c. 3,000 lb. in farms per lactation; yields as high as 7,269 lb. have been recorded |
| Ongole | Ongole tract in Nellore and Guntur districts in Madras | Good milkers; c. 3,000 lb. (up to 5,000 lb. in farms) per lactation |
| Rath | North and west of Alwar state and adjacent territory enclosing portions of Rajasthan to the north and the west | Fairly good milkers |
| Kangayam | Coimbatore district of Madras | Poor; av. yield 1,800 lb. |

* *Misc. Bull., I.C.A.R., No. 27, 1945*

TABLE 5—BREEDS OF BUFFALOES

| Breed | Locality | Remarks |
|---------------|---|---|
| Jaffarabadi | Gir forest of Kathiawar | Good milkers |
| Mehsana | Mehsana district of Baroda and adjoining areas | |
| Murrah | East Punjab, Delhi and northern U.P.; best specimens found in Rohtak and Gohana tehsils of Rohtak district, Hansi and part of Hissar tehsil of Hissar district; Jind tehsil of Jind state; Nabha and Patiala states | Very good milkers; over 4,000 lb. in farms; individuals yielding up to c. 10,000 lb. per lactation recorded |
| Nili and Ravi | Ferozepur district of Punjab | Good milkers; 3,500 lb. per lactation |
| Surti | Gujarat in Bombay and Deccan | Economical milkers; 3,650 lb. per lactation |

DAIRY INDUSTRY

TABLE 6—BREEDS OF GOATS

| Breed | Locality | Remarks |
|---------------|---|-------------------------------------|
| Jamna Pari | Ganges, Jamuna, and Chamber riverain tracts | Good milkers; 540 lb. per lactation |
| Beetal | Punjab, Gurdaspur | Good milkers; 356 lb. per lactation |
| Bar-bari | Uttar Pradesh | Good milkers; 307 lb. per lactation |
| Cutchi | Kathiawar and Kutch | Good milkers; 3-4 lb./day |
| Osmanabad | Hyderabad | 2 5 lb./day |
| North Gujarat | Kathiawar, Kutch, and North Gujarat | Good milkers |
| Marwari | Jodhpur | Medium milkers |
| Surti | Near Surat | Good milkers |
| Sirohi | Sirohi and Palampur | Good milkers |
| Malabari | North Malabar | Good milkers; 2-8 lb./day in farms |
| Zalawadi | Kathiawar | Good milkers |



FIG. 2—BAR-BARI GOAT FROM ETAWAH FARM IN U.P.

Murrah she-buffaloes are the most efficient milk and butter fat producers. They are used for milk and ghee production in almost all large cities and in rural areas in the north and the west. The Mehsana breed is common in Bombay State. They are particularly valued because of their early maturity, long lactation period, and regularity in breeding. The milk yield from Jaffarabadi breed is high.

Goats are used all over India for supplementing deficiencies in milk production. The goat is considered to be the "poor man's cow". About 17.5% of the goat population is used for milk production (*Agric. Marketing India, Rep. Marketing Milk, Marketing Ser., No. 64, 10*). Table 6 gives the main breeds of goats in India.

Table 7 gives the breeds of cattle commonly maintained in breeding and dairy farms in different States.

Breeding—Rearing of bulls of proved breeds for distribution in villages is undertaken in Govern-

ment farms. The bulls are used for selective breeding in areas of well-defined breeds. Attempts are being made to upgrade non-descripts in several areas by repeated forward crossing. These attempts have given encouraging results, but the number of bulls available for breeding purposes is inadequate. Individual observations show that the progeny of Sahiwal, Sindhi, Haryana, or other well-defined bulls, yields at least twice as much milk as the non-descript dam. The second cross shows a further increase.

A considerable amount of cross-breeding work using imported bulls has been carried out during the last 50 years, particularly in military dairy farms. In the earlier years, the breed favoured in India was the Ayreshire. A large number of Friesians were later imported; they are reported to have given better results.



FIG. 3—GADDI GOATS (BUCK AND DOE) FROM HIMACHAL PRADESH



Sahiwal Cow



Tharparkar Cow



Rath Cow



Hissar Cow



Todakina Cow



Murrah Buffalo

SOME BREEDS OF INDIAN COWS

DAIRY INDUSTRY

TABLE 7—BREEDS OF CATTLE IN BREEDING AND DAIRY FARMS *

| | Cows | Buffaloes | Bulls | Bullocks |
|---------------------|--|--|--|--|
| Bhopal | Malvi | .. | Malvi | |
| Bihar | Tharparkar, Hariana, Sahiwal, Murrah, Sindhi, Hissar, Tikoria, Shahabad, and Bachaur | Tharparkar, Murrah, Sindhi, Sahiwal, Hissar, and Bachaur | Sahiwal, Tharparkar, Hissar, Murrah, Shahabad, Bachaur, Taylor, Hariana, and local | Sahiwal, Tharparkar, Hissar, Murrah, Shahabad, Bachaur, Taylor, Hariana, and local |
| Coorg | Sindhi, Hallikar, Gir, and Murrah | Sindhi and foreign breed | Sindhi, Murrah, and foreign breed | |
| Delhi | Sahiwal, Hissar, and Hariana | .. | n.a. | n.a. |
| Punjab | Sahiwal and Hariana | Murrah | Sahiwal and Murrah | Sahiwal |
| Himachal Pradesh | Haryana, Sahiwal, Sindhi, and local | Nilibar | n.a. | Haryana and local |
| Madras | Ongole, Sindhi, Kangayam, Hallikar, and Tharparkar | Murrah and Delhi | Ongole, Delhi, Sindhi, Kangayam, Hallikar, and Murrah | Ongole, Sindhi, Kangayam, Hallikar, cross-breed, and Tharparkar |
| Orissa | Haryana, Murrah, Sindhi, and Multani | Murrah and Sindhi | Sindhi, Hariana, Murrah, and Tharparkar | Haryana and Tharparkar |
| Uttar Pradesh | Haryana, Ponwar, Sindhi, and Kheragarh | Murrah and Etawah | Hissar, Hariana, Sahiwal, Sindhi, Kheragarh, Ponwar, Murrah, and Terai | Murrah, Hariana, Sahiwal, and Kheragarh |
| Cochin | Kangayam, Nagpur, Sindhi, Ongole, Tharparkar, Hariana, and Gir | Nagpur, Delhi, and local | Sindhi, Ongole, cross-breed, Kangayam, Hariana, Tharparkar, and local | Sindhi, Ongole, Gir, Hariana, and Tharparkar |
| Kashmir | Sindhi | .. | Sindhi | Sindhi and local |
| Mysore | Amrit Mahal | .. | Amrit Mahal | Amrit Mahal |
| Travancore | Sindhi and Ayreshire | Murrah and local | Sindhi and local | n.a. |
| Madhya-Bharat | n.a. | n.a. | Malvi | n.a. |
| PEPSU | Montgomery and Kabuli | Murrah and Nilibar | n.a. | n.a. |
| Rajasthan† | Haryana, Sahiwal, Sanchore, and Tharparkar | Murrah and local | Nagauri, Tharparkar, Hariana, and Sahiwal | Murrah, Malvi, Nagauri, Sahiwal, and local |
| IDRI,‡ Bangalore | Sindhi and Gir | n.a. | Sindhi, Gir, Murrah, and Ayreshire | n.a. |

* *Live-stock Statistics*, 1950, 50

n.a. Not available

† Relates to Jaipur and Jodhpur states only

‡ Indian Dairy Research Institute

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TABLE 8—PERFORMANCE OF FRIESIAN AND CROSS-BRED CATTLE IN MILITARY FARMS (1937-38)*

| Breed | No. of records averaged | Av. age in lactation (year) | Av. lactation yield (lb.) | Av. lactation period (days) | Av. dry period (days) |
|--------------------------|-------------------------|-----------------------------|---------------------------|-----------------------------|-----------------------|
| Friesian | .. 5 | 2.2 | 6,721 | 241 | 111 |
| Cross-bred 7/8 | .. 86 | 1.9 | 6,180 | 321 | 126 |
| do. 3/4 | .. 396 | 2.6 | 6,664 | 329 | 120 |
| do. 5/8 | .. 204 | 3.0 | 6,985 | 324 | 123 |
| do. 1/2 | .. 589 | 4.2 | 6,977 | 331 | 118 |
| do. 1/4 | .. 175 | 3.8 | 5,982 | 329 | 156 |
| do. 1/8 | .. 21 | 2.7 | 4,839 | 307 | 160 |
| Miscellaneous cross-bred | .. 143 | 3.9 | 6,029 | 320 | 86 |

* *Misc. Bull., I.C.A.R., No. 36, 1941, 6*

Table 8 summarizes the results of performance of Friesian and cross-bred Indian cattle. The term Friesian is applied to animals with 31/32 or more of Friesian blood. The dams are mostly Sindhi or Sahiwal, rarely Haryana. The cross-breeds are classified in accordance with the proportion of Friesian blood they contain.

The Indian Friesian yields on an average 6,700 lb. of milk per lactation as compared to 9,000-10,000 lb. given by Friesian cows. The Friesians are regular calvers; their productivity, however, is dependent on the care and attention given to them. They are maintained in favourable areas and moved to the hills in summer. The half-breeds yield about 6,900 lb. of milk (Table 8) and the yield goes down as the percentage of Friesian blood is increased or decreased. It has been found that an increase in the proportion of foreign blood increases the capacity to produce, but the constitution of the animal is not equal to the strain imposed in producing the milk to capacity. Back crossing the half-bred to the indigenous bull gives the $\frac{1}{4}$ progeny with improved constitution but low milk yield. Thus the $\frac{1}{4}$ gives an average of 5,900 lb. and the $\frac{1}{8}$, an average of 4,800 lb. These crosses can stand the Indian climate and do not require any special attention. The $\frac{3}{8}$ -bred cow, obtained by crossing forward the $\frac{1}{4}$ -dam with Friesian bull, gives almost the same milk yield as the half-bred cow. Although cross-breeding with foreign breeds improves the milk production, it is not widely adopted as the animals need expert care and management, not usually given to cattle in India.

Experience shows that the cow produced by repeatedly back-crossing the half-bred is superior to the cow started with. Table 9 gives the results of breeding with Jerseys at the Allahabad Agricultural Institute.

For the more effective utilization of the limited number of breeding bulls now available, artificial insemination has been introduced in certain centres. Nearly 28,000 cattle—buffaloes, sheep, and goats—have been inseminated at the 4 re-

TABLE 9—CROSS-BREEDING SINDHI COW WITH JERSEY BULL & BACK-CROSSING WITH SINDHI BULL*

| | No. of lactations (av.) | Av. yield per lactation (lb.) |
|--------------------------|-------------------------|-------------------------------|
| Red Sindhi | 225 | 3,084.5 |
| Jersey-Sindhi | 129 | 4,551.6 |
| 1/4 Jersey-3/4 Sindhi | 148 | 3,916.9 |
| 1/8 Jersey-7/8 Sindhi | 27 | 3,754.7 |
| 1/16 Jersey-15/16 Sindhi | 6 | 3,891.3 |

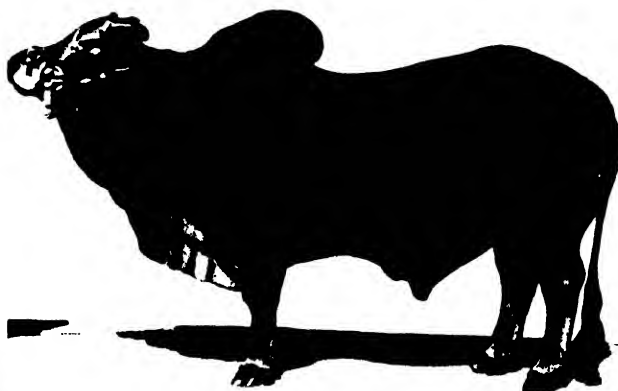
A brief review of the progress and present position regarding the productivity of live-stock in India. Minist. Agric., New Delhi, 1950, 35

gional research centres in Calcutta, Patna, Montgomery, and Bangalore, in addition to the station at Izatnagar, where nearly 1,000 animals are inseminated annually. This method is being increasingly applied in different States. It is proposed to inseminate a total of 3.7 million milch cattle, representing about 10% of the cattle population, in the next 5 years in the progressive proportion of 5, 15, 35, 65, and 100%. A total of 74 'seed bull' centres and 370 insemination yards will be required for this purpose. The increase in milk production is expected to be 1.90 lakh md. in the second year, rising to 25.74 lakh md. in the fifth year. The total increase over the 5-year period will be 42.88 lakh md. (*Agric. Anim. Husb., U.P., 1951, 1 (12), 21; Proposals for a five-year plan for increasing milk production with proposed targets, Minist. Agric., New Delhi, 1947, 16*).

Feeding stuffs—Feeding stuffs for dairy cattle may be broadly classified into roughages and concentrates. The roughages consist of succulent feeds (natural grazing, cultivated grasses, cultivated fodders, and root crops) and dry fodders (hay, straw, and chaff). The concentrates consist of carbohydrate-rich materials (legume grains and cereal grains) and protein-rich materials (oilseeds, oilseed cakes and meals). In addition to roughages and concentrates, dairy animals also require a certain amount of common salt to keep



Deoni Bull



Sahiwal Bull



Kankrej Bull



Hissar Bull



Haryana Bull



Gir Bull

SOME BREEDS OF INDIAN BULLS

TABLE 10—AVAILABLE CATTLE FEEDING STUFFS IN INDIA

| Natural grasses | Cultivated grasses | Cultivated fodders | Roots and tubers | Hay | Straw | Concentrates | | |
|---|---|--|--|---|--|---|---|---|
| | | | | | | Oil cakes | Oil seeds | Grain & seeds |
| Dhub (<i>Cynodon dactylon</i>) | Elephant grass (<i>Pennisetum purpureum</i>) | Juar or cholam (<i>Sorghum vulgare</i>) | Turnip (<i>Brassica rapa</i>) | Lucerne (<i>Medicago sativa</i>) | Oat | Groundnut (<i>Arachis hypogaea</i>) | Linseed | Gram (<i>Cicer arietinum</i>) |
| Anjan (<i>Cenchrus ciliaris</i>) | Guinea grass (<i>Panicum maximium</i>) | Bajra or cumbu (<i>Pennisetum typhoides</i>) | Swedes (<i>Brassica napobrassica</i>) | Berseem (<i>Trifolium alexandrin- num</i>) | Barley (<i>Hordeum vulgare</i>) | Linseed (<i>Linum ustatissimum</i>) | Sunflower (<i>Helianthus annuus</i>) | Arhar (<i>Cajanus cajan</i>) |
| Palwan (<i>Dichanthium annulatum</i>) | Sudan grass (<i>Sorghum sudanicum</i>) | Ragi or mandal (<i>Eleusine coracana</i>) | Beet (<i>Beta rularis</i>) | Oat | Wheat (<i>Triticum aestivum</i>) | Palm kernel (<i>Elaeis guineensis</i>) | | Guara (<i>Cyamopsis tetragonoloba</i>) |
| Chimbar (<i>Eleusine flagellifera</i>) | Rhodes grass (<i>Chloris gayana</i>) | Oats (<i>Avena sativa</i>) | Beet tops | | Lucerne | Coconut (<i>Cocos nucifera</i>) | | Mattar (<i>Pisum sativum</i>) |
| Spear grass (<i>Heteropogon contortus</i>) | Teosinte (<i>Euchlaena mexicana</i>) | Cheena (<i>Panicum niliacum</i>) | Potatoes (<i>Solanum tuberosum</i>) | | Legume | Sesame (<i>Sesamum indicum</i>) | | Rawan (<i>Vigna sinensis</i>) |
| Eremopogon foecolatus | | Velvet beans (<i>Strobilium dierlingianum</i>) | Carrots (<i>Daucus carota</i>) | | Bean (<i>Vicia faba</i>) | Rapeseed (<i>Brassica spp.</i>) | | Moth (<i>Phaseolus aconitifolius</i>) |
| Chrysopogon montanus | | Maize (<i>Zea mays</i>) | | | Pea (<i>Pisum sativum</i> var. <i>arvense</i>) | Cottonseed (<i>Gossypium spp.</i>) | | Oats |
| Cymbopogon schoenanthus | | Lucerne | | | Paddy (<i>Oryza sativa</i>) | | | Wheat |
| | | Berseem | | | | | | Wheat by-products |
| | | Persian clover or shaftal (<i>Trifolium resupinatum</i>) | | | | | | Barley |
| | | Indian clover or senji (<i>Medicago parriflora</i>) | | | | | | Paddy |
| | | Sunflower | | | | | | Maize |

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them in good condition. Table 10 gives the different types of feeding stuffs available in India.

Investigations covering a period of ten years have shown that a number of materials, hitherto considered as wastes, can be utilized as cattle feed, e.g. mango seed kernel, jaman seed, and mahua flowers (concentrates), and groundnut husk, bajra and coffee husk (roughages). In addition, brewery and distillery by-products (malt sprouts, wet and dried brewery grain, millets, and molasses) and feeds of animal origin, e.g. fish meal, bone meal, and blood meal, may be employed as cattle feeds.

Table 11 gives the feeding stuffs commonly fed to dairy cattle in India.

Maintenance rations—A well fed dairy cow producing 1 lb. of butter fat per day utilizes about 48% of the food consumed for maintenance. If the ration is cut down to about two-thirds, the cow will still need the same quantity of food for maintenance, but the quantity available for milk production is reduced (Lander, 290).

The results of maintenance ration trials (covering a period of 22 years) on cows and heifers

TABLE 11—FEEDING STUFFS FOR DAIRY CATTLE*

| Dry roughage | Green fodder | Concentrate |
|---------------------|--|-----------------|
| Wheat <i>bhusa</i> | Maize | Gram |
| Oat hay | Lucerne | Bran |
| Rice straw | Berseem | Arhar |
| Maize stalks | Shaftal | Cottonseed |
| Juar stalks | Senji | Cottonseed cake |
| Legume <i>bhusa</i> | Oat | Sarson cake |
| Grass hay | Juar (chulam) | Toria cake |
| Bajra stalks | Bajra (cumbu) | Linseed cake |
| Berseem hay | Guara | Til cake |
| | Guinea grass | Groundnut cake |
| | Elephant grass | |
| | Napier grass | |
| | Silage of oats, maize, or mixture of juar & guara or maize & guara | |

* Lander, 305

show that animals fed on green fodders and hays remain fit for a long time (but not indefinitely) with a positive nitrogen balance. The maintenance requirements of dry cows and heifers are shown in Table 12.

Table 13 gives the feed requirements, in terms of total digestible nutrients and digestible proteins, of a cow in calf giving 2 gallons of milk per day.

Table 14 gives the composition of rations which are considered adequate for dairy cows. The quantities shown in the Table may be exceeded during the period preceding calving and protein-rich concentrates with cereals and hay, preferably legume hay, should be given.

TABLE 12—MAINTENANCE REQUIREMENTS OF DRY COWS (wt., 800-1,000 lb.) AND HEIFERS (wt., 300 lb.)*

| Fodder | Requirements per day (lb.) | Dry roughage | Requirements per day (lb.) |
|--------------------|----------------------------|--------------|----------------------------|
| Oats | 40-50 | Oat hay | 11-12 |
| Senji | 70-90 | Berseem hay | 12-13 |
| Berseem | 70-85 | Senji do. | 12-13 |
| Maize | 60-70 | Maize do. | 15-16 |
| Guara | 50-70 | | |
| Velvet beans | 60-80 | | |
| Bajra | 50-60 | | |
| Elephant grass | 60-80 | | |
| Guinea do. | 40-60 | | |
| Sunflower (tender) | 50-75 | | |

* Lander, 115

TABLE 13—FEED FOR DAIRY COWS (wt., 800 lb.)*

| | Total digestible nutrients (lb.) | Digestible proteins (lb.) |
|--------------------------------|----------------------------------|---------------------------|
| For maintenance | 6.19 | 0.46 |
| For milk production (5.0% fat) | 7.14 | 0.96 |
| For the calf | 1.00 | 0.20 |
| Total | 14.33 | 1.62 |

* Lander, 311

TABLE 14—RATIONS FOR DAIRY COWS*

| North India (Qty in lb.) | | | | South India | | | |
|----------------------------|-------|----------------------------|-------|----------------------------|-------|----------------------------|-------|
| Ration 1 | | Ration 2 | | Ration 1 | | Ration 2 | |
| Maize green | 60 | Berseem | 60 | Cambu green | | Chulam green | 50 |
| Wheat bran | 4 | Wheat <i>bhusa</i> | 6 | Chulam straw | | Kollukottai grass hay | 5 |
| Gram | 2 | Bran | 2 | Coconut cake | | Groundnut cake | 2 |
| Toria cake | 1.50 | Maize | 6 | Cottonseed meal | | Gram husk | 2 |
| Total digestible nutrients | 14.55 | Total digestible nutrients | 14.40 | Rice bran | | Total digestible nutrients | 14.14 |
| Digestible protein | 1.65 | Digestible protein | 1.80 | Total digestible nutrients | 14.93 | Digestible protein | 1.59 |
| | | | | Digestible protein | 1.64 | | |

* Lander, 311

TABLE 15—SUMMER RATIONS FOR BUFFALOES*

(Qty in lb.)

| | (1) | (2) | (3) |
|----------------------------|-------|-------|-------|
| Green maize | 105 | 125 | .. |
| Jowar and guara | .. | .. | 70 |
| Wheat <i>bhusa</i> | 5 | 5 | 15 |
| Bran | 5 | 6.50 | .. |
| Gram | 1 | 2.16 | 1 |
| Toria cake | 3 | 2.16 | 1 |
| Cottonseed | .. | 2.16 | 2 |
| Dry matter | 34.98 | 43.16 | 30.44 |
| Total digestible nutrients | 24.57 | 30.46 | 19.69 |
| Digestible protein | 2.52 | 3.00 | 1.36 |

(1) For a buffalo of 1,400 lb. body weight, giving daily 24 lb. of milk containing 7% fat.

(2) For a buffalo of 1,200 lb. body weight, giving daily 20 lb. of milk containing 6% fat.

(3) For a buffalo in villages

* Lander, 353

Experimental data on the feeding of buffaloes are meagre. Preliminary trials on buffaloes at Lyallpur showed that the maintenance requirements of a buffalo (wt., 1,200–1,400 lb.) in terms of roughage and total digestible nutrients are approximately 1.5 times those required by an average cow of 800 lb. weight. Military dairy farms in India take as their standard a cow of 800 lb. and a buffalo of 1,400 lb. and for the buffalo allow $1\frac{2}{3}$ the amount of roughage and total digestible nutrients given to a cow. A buffalo is a more economic producer of milk than the cow, only if the fodder is cheap. It requires considerably more digestible nutrients per lb. of milk produced than the average cow. Buffalo milk contains a higher percentage of fat and this factor should be taken into account in computing rations for buffaloes.

Table 15 gives suitable summer rations for buffaloes.

Goats are extremely valuable milch animals because they can be maintained at little cost. Goat milk contains a greater variety of minerals and is particularly rich in iron, phosphates, and potassium salts as compared to milks of other animals.

Considerable amount of work on the development of milch goats has been done at the Government Cattle Farm, Hissar, and at the Goat Breeding Establishment, Etah, Uttar Pradesh. A well fed goat produces as much milk as the country cow at less cost. The maintenance requirements for goats are considerably higher than those for cows on account of their much smaller size, and consequently greater body surface, in proportion to their live weight; further, the requirements of total digestible nutrients per lb. of milk produced are also higher. In computing feeds for goats, the requirements are

calculated according to weight as for cows and 20–25% feed added for maintenance; for milk production, 10% total digestible nutrients per pound of milk are added (Lander, 373).

The Indian goat is a browsing animal and its natural feed consists of tender leaves of trees and shrubs. It eats almost any type of green material, including coarse grass, but prefers sweet grass and fodder crops.

Goats should be allowed to graze for 8–9 hr. a day and, in addition, milch animals should be given a mixture of concentrates calculated on the basis of milk production. A mixture which has been found suitable at Hissar consists of 2 parts of gram and 1 part of bran, fed twice daily at the time of milking.

Table 16 gives the compositions of two mixtures found suitable for feeding goats at the Goat Breeding Farm, Etah.

Fodders given to goats at Etah are: Napier and guinea grasses, lucerne, berseem, arhar, cabbage or cauliflower leaves, sann hemp pods, leaves of trees, and weeds. An average goat requires about 8–10 lb. of fodder a day. Green feeds or dry roughages may be tied in bundles and suspended so that the goat can easily get at them.

Table 17 gives a few rations which are adequate for a goat weighing 150 lb. and yielding 5 lb. of milk per day.

Feeding of young stock—The common practice in India is to allow calves to suckle their mothers throughout the lactation period. In other countries, however, the practice is to feed the calves on colostrum for the first few days and on whole

TABLE 16—COMPOSITION OF CONCENTRATE MIXTURES FOR GOATS*

| | Parts by wt. | |
|--|--------------|-----|
| | (1) | (2) |
| Crushed barley | 1 | 15 |
| Crushed maize | 2 | 15 |
| Linseed or mustard cake | 2.25 | 20 |
| Heavy wheat bran, i.e. bran produced by hand milling | 2 | .. |
| Wheat bran | .. | 50 |

2% of a mineral mixture or salt should be added

* Lander, 379

TABLE 17—REPRESENTATIVE RATIONS FOR GOATS*

| | Parts by wt. | | | |
|--------------------------------------|--------------|-----|-----|-----|
| | (1) | (2) | (3) | (4) |
| Ground barley | 1 | 1 | .. | 1 |
| Wheat bran | 1 | 1 | 1 | 1 |
| Dried beet or turnip pulp | 1 | 6 | 1 | 3 |
| Coconut meal | 1 | .. | .. | .. |
| Cottonseed cake meal or coconut meal | .. | 2 | 1 | .. |
| Oats | .. | .. | 1 | .. |

* Lander, 379

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TABLE 18—FEEDING OF YOUNG STOCK *

| Age | Cow | | | | Buffalo | | | | Cow and Buffalo | |
|-------------------|-------------------------------|---------------|----------------------------|----------------------------|-------------------------------|---------------|----------------------------|----------------------------|-----------------|----------------------------|
| | Dam's colo- strum (lb.) | Milk (lb.) | Separated milk (lb.) | Concen- trates (lb.) | Dam's colo- strum (lb.) | Milk (lb.) | Separated milk (lb.) | Concen- trates (lb.) | Fodder (lb.) | No. of feedings/ day |
| 1st to 3rd day | 1.0 | .. | .. | .. | 1.0 | .. | .. | .. | .. | 3 |
| 4th to 7th day | .. | 1.0 | .. | .. | .. | 1.0 | .. | .. | .. | 3 |
| 2nd week | .. | 1.25 | .. | .. | .. | 0.8 | 0.1 | .. | .. | 2 |
| 3rd do. | .. | 1.25 | .. | .. | .. | 0.8 | 0.2 | .. | .. | 2 |
| 4th do. | .. | 1.0 | 0.25 | 1/20 | .. | 0.7 | 0.2 | 1/20 | .. | 2 |
| 5th do. | .. | 1.0 | 0.25 | 1/20 | .. | 0.6 | 0.4 | 1/20 | 1/20 | 2 |
| 6th do. | .. | 1.0 | 0.25 | 1/20 | .. | 0.5 | 0.4 | 1/20 | 1/10 | 2 |
| 7th do. | .. | 0.75 | 0.40 | 1/12 | .. | 0.4 | 0.4 | 1/10 | 1/8 | 2 |
| 8th do. | .. | 0.75 | 0.40 | 1/12 | .. | 0.3 | 0.5 | 1/10 | 1/8 | 2 |
| 9th do. | .. | 0.75 | 0.40 | 1/12 | .. | 0.2 | 0.6 | 1/10 | 1/6 | 2 |
| 10th to 12th week | .. | 0.50 | 0.50 | 1/12 | .. | 0.1 | 0.5 | 1/10 | 1/5 | 2 |
| 13th to 16th do. | .. | 0.25 | 0.50 | 1/12 | .. | .. | 0.5 | 1/10 | 1/5 | 2 |
| 17th to 19th do. | .. | .. | 0.40 | 1/12 | .. | .. | 0.4 | 1/10 | 1/4 | 2 |
| 20th to 23rd do. | .. | .. | 0.25 | 1/12 | .. | .. | 0.3 | 1/10 | 1/3 | 2 |
| 24th to 26th do. | .. | .. | 0.10 | 1/12 | .. | .. | 0.2 | 1/10 | 1/3 | 2 |

[Figures under all heads, except fodder, denote quantity of feed per 10 lb. body weight. Figures under fodder show actual proportion of maintenance ration using the ration fed to a cow weighing 800 lb. as standard]

* Lander, 328

TABLE 19—DIGESTIBILITY AND NUTRITIVE RATIOS OF FEEDING STUFFS*
(1,000 tons)

| | Available quantity | Digestible crude protein | Digestible carbohydrates | Digestible fats | Total digestible nutrients | Nutritive ratio |
|---------------|-----------------------|--------------------------------|-----------------------------|--------------------|----------------------------------|--------------------|
| Dry fodders | 111,000 | 1,010 | 34,580 | 383 | 36,480 | 1:36.0 |
| Green fodders | 100,000 | 1,000 | 10,000 | 250 | 11,562 | 1:10.6 |
| Concentrates | 1,500 | 450 | 375 | 150 | 1,163 | 1:1.6 |
| Cottonseed | 2,300 | 300 | 690 | 367 | 1,818 | 1:5.1 |
| Total | 214,800 | 2,760 | 45,645 | 1,150 | 51,023 | 1:17.5 |

* Wright, *Report on the Development of Cattle and Dairy Industries of India*, I.C.A.R., 1937, 175

milk, either by suckling or by pail feeding, for three or four weeks; they are given other feeds after this period.

Table 18 gives the feeding schedule for young stock in military dairy farms in India.

Table 19 gives the digestibility and nutritive ratio of some feeding stuffs.

The total requirements of proteins and carbohydrates for feeding India's bovine stock are estimated to be as follows: digestible proteins, 14,294,600 tons; and starch equivalent, 108,380,000 tons. The available supplies of roughages and concentrates provide only 42.7% of the requirements of digestible proteins and 56.6% of the starch equivalent (Sikka, *World Crops*, 1951, 3, 382).

The total resources of cattle feeds in India fall short of the requirements, and a large number of cattle live on whatever they can pick from fallow lands. Grazing is available only for a few months during the monsoon (July-October), after which the fodder supply declines, reaching a low level in the hot weather. Table 20 summarizes the available information on the fodder resources in different States.

TABLE 20—RESOURCES OF FODDER, CONCENTRATES, AND GRAZING AREAS IN DIFFERENT STATES*

| | Roughage per head per year (lb.) | Concentrates per head per year (lb.) | Grazing area available per animal (acres) |
|----------------|---|---|--|
| Ajmer-Merwara | 1,013.4 | 54.66 | .. |
| Assam | 853.4 | 43.01 | 2.50 |
| Bengal | 1,142.7 | 51.74 | 0.30 |
| Bihar | 1,008.8 | 89.82 | 0.75 |
| Bombay | 6,231.2 | 180.54 | 1.10 |
| Madhya Pradesh | 1,873.6 | 87.14 | 2.30 |
| Coorg | 1,339.9 | 36.74 | .. |
| Delhi | 5,057.4 | 55.78 | .. |
| Madras | 1,994.2 | 169.57 | 1.20 |
| Orissa | 1,228.4 | 53.76 | 0.75 |
| Punjab | 6,543.7 | 107.52 | 1.10 |
| Uttar Pradesh | 1,955.7 | 35.84 | 0.60 |

* *Rep. Cattle Preservation & Development Committee*, Minist. Agric., New Delhi, 1948, 74.

According to the investigations carried out in veterinary research stations in India, the average requirements of salt per head of cattle is c. 38 lb. per annum.

Table 21 gives the imports and exports of fodder, bran and pollards into and from India.

TABLE 21—IMPORTS AND EXPORTS OF FODDER, BRAN AND POLLARDS

| | Imports | | Exports | |
|---------------|----------------|---------------|----------------|---------------|
| | Qty. (cwt.) | Val. (Rs.) | Qty. (cwt.) | Val. (Rs.) |
| 1933/34— | | | | |
| 1938/39 (av.) | 45,092 | 1,18,679 | 1,69,926 | 52,97,844 |
| 1939/40 | | | | |
| 1943/44 (av.) | 33,517 | 99,362 | 10,797 | 5,98,802 |
| 1944-45 | 9 | 43 | 1,988 | 3,12,294 |
| 1945-46 | | 7 | 1,456 | 1,88,922 |
| 1946-47 | 2,934 | 35,140 | 513 | 1,05,474 |
| 1947-48 | 5,237 | 67,591 | 1 | 480 |
| 1948-49 | 2,46,049 | 49,75,104 | | |
| 1949-50 | 2,31,230 | 38,17,759 | | |
| 1950-51 | 2,67,542 | 45,31,809 | | |
| 1951-52 | 78,433 | 17,96,303 | | |

Diseases—The main diseases of dairy cattle in India are rinderpest, haemorrhagic septicaemia, black quarter fever, anthrax, foot-and-mouth disease, "Three-day" fever, cow-pox, pleuropneumonia, tuberculosis, Jone's disease, actinomycosis, Bang's disease, tick fever, surra, tetanus, rabies, white scour, naval ill, calf diptheria, and coccidiosis. Vaccines and antisera for cattle diseases are produced in the Central Depot at Izatnagar and in serum institutes established in different States. The institutes at Izatnagar and Mukteswar prepare the following products: rinderpest sera, anthrax serum, anthrax spine vaccine, haemorrhagic septicaemia serum and vaccine, black quarter serum and vaccine, bovine absorption vaccine, tuberculine (ordinary and concentrated), rinderpest bull virus, rinderpest goat virus and goat tissue virus, and *Brucella abortus* antigen (Das Gupta, II, 262).

MILK PRODUCTION AND DISTRIBUTION

Reliable data on milk records of dairy animals are not available, except of those maintained in Government dairy farms and a few private farms. Table 22 gives the milking records of important breeds.

The Indian Council of Agricultural Research conducted a rapid survey of milk yields in 7 village breeding tracts during 1936. Table 23 gives the average milk yields of cows and buffaloes in the tracts surveyed.

Table 24 gives the cattle population of India grouped according to milk yields.

The yield of milk from nearly half the number of cows in India varies between 1 and 2 lb. per day; it is about $\frac{1}{2}$ lb. per day from about a third of the number of cows; only 2.7% of the cow population yields 3-4 lb. of milk per day.

The estimated average yield of hand drawn milk per cow is 413 lb. per annum; the corresponding figure per buffalo is 1,101 lb. Table 25

gives the average annual milk yield per cow, buffalo, and goat in different States. Yields of milk per lactation from cows in different countries of the world are recorded in Table 26.

TABLE 22—MILK YIELDS*

| Breed | Purchased stock (lb.) | Farm-bred stock (lb.) |
|---|-----------------------------|-----------------------------|
| Cow | | |
| Deoni | 2,943 | 2,673 |
| Gir | 2,753 | .. |
| Haryana | 3,400 | 3,459 |
| Kankrej | 3,407 | 3,232 |
| Krishna valley | 2,595 | .. |
| Malvi | 2,863 | 2,469 |
| Ongole | | 2,938 |
| Sahiwal | | |
| (a) all types | 3,735 | 4,269 |
| (b) Ferozepur farm | | 5,717 |
| Sindhi | | |
| (a) all types | 3,534 | 3,604 |
| (b) Military dairies | 4,150 | .. |
| Tharparkar | 3,438 | 4,056 |
| Buffalo | | |
| Murrah | | |
| (a) all types | 4,427 | 4,113 |
| (b) Military dairies (northern circle) | 3,771 | .. |
| (c) Military dairies (southern circle) | 4,230 | 4,643 |
| Nili | 5,212 | .. |
| Surti | 3,576 | 4,359 |
| * Rep. Marketing Milk 7 | | |

TABLE 23—AVERAGE MILK YIELDS PER LACTATION IN DIFFERENT TRACTS*

| | Cows (lb.) | She-buffaloes (lb.) |
|----------------|---------------|------------------------|
| Montgomery | 1,343.8 | 2,470.0 |
| Haryana | 986.0 | 2,575.4 |
| Kosi | 865.0 | 1,768.4 |
| Bihar | 651.3 | 1,254.7 |
| Madhya Pradesh | 411.3 | 1,513.1 |
| Kankrej | 919.8 | 1,890.2 |
| Ongole | 1,236.4 | 1,903.4 |

Misc. Bull. I.C.A.R., No. 22, 1939.

TABLE 24—NUMBER OF MILCH CATTLE ACCORDING TO MILK YIELDS*

| Yield per lactation (lb.) | Cows (no. in lakhs) | She-buffaloes (no. in lakhs) |
|------------------------------|------------------------|---------------------------------|
| Up to 185 | 117.56 | .. |
| 186-365 | 66.62 | 1.62 |
| 366-730 | 203.50 | 35.89 |
| 731-1,095 | 12.30 | 73.33 |
| 1,096-1,460 | 11.03 | 48.28 |
| 1,461-1,825 | | 16.22 |
| 1,826-2,190 | | 2.74 |
| 2,191-2,555 | | 17.64 |
| Total | 411.01 | 195.72 |

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TABLE 25—AVERAGE ANNUAL MILK YIELD PER ANIMAL IN DIFFERENT STATES*
(Qty in lb.)

(The average yield relates to animals kept for breeding or milk production)

| | Cow | Buffalo | Goat |
|--------------------|-------|---------|------|
| Assam | 140 | 315 | 80 |
| Bihar | 620 | 1,526 | 340 |
| Bombay | 140 | 840 | 115 |
| Madhya Pradesh | 65 | 545 | 110 |
| Madras | 450 | 800 | 180 |
| Orissa | 245 | 600 | 200 |
| Punjab | 1,445 | 2,320 | 440 |
| Uttar Pradesh | 625 | 1,240 | 125 |
| West Bengal | 420 | 960 | 80 |
| Hyderabad | 170 | 825 | 50 |
| Kashmir | 230 | 570 | 90 |
| Madhya Bharat | 320 | 645 | 100 |
| Mysore | 240 | 590 | 180 |
| PEPSU | 970 | 1,667 | 225 |
| Rajasthan | 750 | 900 | 100 |
| Saurashtra | 1,000 | 2,500 | 200 |
| Travancore-Cochin† | 410 | 910 | 95 |
| Vindhya Pradesh | 65 | 445 | 100 |
| Delhi | 1,270 | 2,000 | 110 |
| Himachal Pradesh | 900 | 1,200 | 200 |
| Other areas | 431 | 826 | 107 |
| All India | 413 | 1,101 | 134 |

* Indian Live-stock Statistics, 1947-48 to 1949-50, 1952, 58

† Figures relate to Travancore only

TABLE 26—YIELD PER LACTATION FROM COWS IN DIFFERENT COUNTRIES*

| | (Qty in lb.) | | |
|-------------|--------------|---------------------|-------|
| Austria | 2,648 | Argentina | 1,715 |
| Belgium | 6,362 | Chile | 2,947 |
| Denmark | 5,291 | Uruguay | 382 |
| Finland | 3,165 | Burma | 413 |
| France | 2,548 | Indian Union (1945) | |
| Ireland | 3,995 | Cows | 413 |
| Netherlands | 4,885 | Buffaloes | 1,101 |
| Norway | 3,118 | Syria | 3,864 |
| Sweden | 5,742 | Egypt | 1,409 |
| Switzerland | 5,806 | Australia | |
| U.K. | 7,658 | Commonwealth | 4,802 |
| Canada | 4,408 | Queensland | 3,440 |
| Guatemala | 9,964 | Tasmania | 4,869 |
| U.S.A. | 3,218 | New Zealand | 5,660 |

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TABLE 28—PRODUCTION AND AVAILABLE MARKETABLE SUPPLY OF MILK*

| | Cow | Buffalo | Goat | Total |
|--|---------|---------|-------|---------|
| Milking animals (lakhs) | 411 | 196 | 82 | 689 |
| Annual yield of hand-drawn milk per animal (lb.) | 413 | 1,101 | 134 | |
| Annual gross production of milk (lakh md.) | 2,721.8 | 2,921.9 | 183.2 | 5,826.9 |
| Milk consumed by calves and lambs (lakh md.) | 659.4 | 302.2 | 49.8 | 1,011.4 |
| Annual net production of hand-drawn milk (lakh md.) | 2,062.4 | 2,619.7 | 133.4 | 4,815.5 |
| Total production (%) | 42.8 | 54.4 | 2.8 | (100) |
| Milk retained by producers for domestic use (lakh md.) | 614.0 | 205.0 | 67.0 | 886.0 |
| Marketable quantity as fluid and products (lakh md.) | 1,448.4 | 2,414.7 | 66.4 | 3,929.5 |

* Brochure Marketing Milk, 6, 9

The highest recorded yield per lactation—41,943 lb. or 114.9 lb. per day—is held by Carnation Madcap Ormsby Faync, a Holstein-Friesian cow, in U.S.A. The second place—41,644 lb.—is held by Cherry, an English short-horned cow. According to recent publications, the highest recorded yield in India is 19,682 lb. from a cross-bred cow, and the highest yield from a Sahiwal cow is 14,692 lb. (Warner, Allahabad Fmr, 1949, 23, 43).

Production—Table 27 gives the production of milk in India during 1945.

Milk production is higher in the Indo-Gangetic plain and eastern Rajasthan than in other parts of the country. The production in different States is as follows: U.P., 20.3; Madras, 13.5; Bihar, 10.8; Punjab, 9.1; West Bengal, 7.1; Rajasthan, 5.4; other States, 33.8%. U.P. accounts for 26.0% of the total buffalo milk produced in India, followed by Punjab with 15.0% (Rep. Marketing Milk, 9). Table 28 summarizes the data on gross production and net available supply of milk in India.

Taking into account imports and exports for 1945-46 (6.04 and 0.25 lakh md. respectively in terms of fluid milk) the net available marketable supply works out to 3,935.3 lakh md. (Table 28).

TABLE 27—PRODUCTION OF MILK IN INDIA (1945)*
(lakh maunds)

| | Cow milk | Buffalo milk | Goat milk | Total |
|-------------------|----------|--------------|-----------|----------|
| Assam | 19.94 | 5.67 | 0.87 | 26.48 |
| Bihar | 222.71 | 217.46 | 2.74 | 442.91 |
| Bombay | 59.35 | 249.52 | 9.99 | 318.96 |
| Madhya Pradesh | 37.88 | 66.75 | 4.30 | 108.93 |
| Madras | 278.60 | 286.12 | 12.18 | 576.90 |
| Orissa | 72.65 | 19.69 | 0.43 | 92.77 |
| Punjab | 188.65 | 391.89 | 17.79 | 598.33 |
| Uttar Pradesh | 417.12 | 684.74 | 17.40 | 1,119.26 |
| West Bengal | 145.90 | 16.07 | 3.29 | 165.26 |
| Hyderabad | 39.86 | 119.09 | 5.96 | 164.91 |
| Jammu and Kashmir | 24.66 | 24.94 | 0.96 | 50.56 |
| Madhya Bharat | 68.37 | 72.82 | 2.39 | 143.58 |
| Mysore | 42.20 | 40.19 | 5.64 | 88.03 |
| PEPSU | 40.97 | 82.43 | 8.25 | 131.65 |
| Rajasthan | 138.95 | 92.25 | 8.81 | 240.01 |
| Saurashtra | 61.87 | 113.50 | 7.91 | 183.28 |
| Travancore | 20.01 | 2.47 | 0.03 | 22.51 |
| Delhi | 4.38 | 9.50 | 0.20 | 14.08 |
| Himachal Pradesh | 40.23 | 19.81 | 2.95 | 62.99 |
| Vindhya Pradesh | 10.41 | 21.49 | 1.32 | 33.22 |
| Other areas | 127.73 | 83.31 | 19.94 | 230.98 |
| Total | 2,062.44 | 2,619.71 | 133.35 | 4,815.50 |

Live-stock Statistics, 1950, 15



FIG. 4—SPECIAL BREEDS OF BUFFALOES BEING MILKED AT THE GOVERNMENT MILK COLONY, AAREY

Specific projects for increasing milk production in India are under the consideration of Government. The targets aimed at are 27.27 lakh maunds of milk in the first year, rising to 313.14 lakh maunds in the fifth year, making a total of 758.02 lakh maunds in 5 years. The production in the fifth year will exceed the present production by 10%.

Processing. In advanced countries a major part of the milk is processed and rendered safe before distributing to consumers. Among the methods employed, pasteurization is the most important. This consists in applying heat for the minimum period necessary to destroy microbial contaminants, the temperature being high enough to kill them but not so high as to affect the chemical and physical characteristics or the nutritive value of milk.

Two methods of pasteurization are in use—the Holding and the Flash or High Temperature Short Time (H.T.S.T.). In the Holding method, the milk is heated to 140–150°F., held at that temperature for 30 minutes and rapidly cooled to 50°F.; in the H.T.S.T. method, the milk is heated to 160–162°F., held at that temperature for 10–20 sec., and cooled immediately to 50°F. A variant of the H.T.S.T. method, known as Stassanization, and

other modifications of both methods are in use. Thermophilic bacteria are not readily destroyed by flash pasteurization but thermophilic bacteria are. Holding pasteurization gives a safe and satisfactory product. Pasteurization does not affect the concentrations of vitamins A and D or of riboflavin. About one-fourth of the thiamin and half of the ascorbic acid are destroyed.

Among the other milk processing methods, irradiation by ultra-violet light, developed in Germany during World War II, is of interest. Irradiation increases the vitamin D content of the milk (*Some Developments in Dairying in Germany, BIOS Final Rep. No. 86, 1946*).

Homogenizing and freezing processes have been developed in America. Milk is homogenized by forcing through a nozzle at high pressure (c. 2,500 lb./sq. in.) in which process fat globules are broken up to about 2 μ or less in diam. so that no visible separation of cream takes place by churning. During World War II, frozen whole milk was made available to Armed Forces in large quantities. Fresh pasteurized milk was frozen rapidly in paper cartons to c. 20°F. The temperature was maintained at 10–15°F. during shipping and storage. The frozen product was

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thawed for one day in a refrigerator at 36-40° F before use (Lampert, 152).

The bulk of the milk is marketed in India in the raw condition. Pasteurization has not been widely adopted in India owing to the difficulty of collecting milk at a reasonable price from rural areas and of finding a market for pasteurized milk.

Pasteurization plants have been set up in a few organized dairies in India. Apart from the military dairy farms, about a dozen farms in the country pasteurize milk. The holding method is generally employed, the milk being heated to c. 145° F. for 30 minutes, and cooled to 40° F., for despatch to camps or hill depots, and to 50° F. for local sale. Where refrigerating plants are not available, pasteurized milk is cooled to 60-65° F. in cold weather by ordinary water; in summer, hot milk is issued to consumers straight from the heater. Experience has shown that milk issued hot gives a lower bacterial count on delivery than milk cooled by water and issued warm (*Rep. Marketing Milk*, 103).

Some of the dairy farms sell pasteurized milk in sterilized bottles. In some cities, pasteurized milk is retailed into consumers' vessels from sealed cans of $\frac{1}{2}$ -1 md. capacity, during which process it is likely to be contaminated. In such

cases pasteurization only increases the marketable life of the milk.

A modern central dairy has been set up in the Aarey Milk Colony, Bombay. The dairy receives milk from colony settlers, outside producers, and co-operative societies in the Bombay area. Raw milk is received in the morning and in the evening. The hours of milking of animals in the colony and outside have been so regulated that different lots of milk keep on arriving at the dairy, as soon as possible after milking, at the rate of about 500 md. per hour. The milk is examined for odour, appearance, visible dirt, and cleanliness of cans, and only those cans, the contents of which satisfy the prescribed standards, are accepted. Samples in duplicate are drawn from each lot of milk for determining the quality, according to which payments are made. The empty cans together with the lids are returned to suppliers after washing, steam-sterilizing, and drying. Two can-washing machines, each handling 1,200 cans per hour, have been installed for this purpose.

Two H.T.S.T. plate pasteurizers, each with a capacity of 2,000 gallons per hour, have been installed in the dairy. The raw milk obtained from producers is clarified in Alpha-Laval



The Milk Commissioner, Bombay

FIG. 5—MILK CANS ARE SUPPLIED TO PRODUCERS FOR BRINGING MILK TO THE DAIRY AT AAREY



The Milk Commissioner, Bombay

FIG. 6—STAINLESS STEEL APV PLATE PASTEURIZERS IN THE DAIRY AT AAREY

clarifiers, heated to 162–170°F., held for 20–12 sec., and cooled to 40°F. The pasteurizers are fitted with flow diversion valves to prevent any sub-temperature (under-heated) milk passing over to the cooling section, thereby assuring that every portion of the milk has been properly pasteurized. The treated milk is stored in 6 insulated stainless steel tanks, each of 2,000 gallons capacity, where the milk can be kept for 3–4 days with negligible rise in temperature or any deterioration in quality. The tanks are fitted with special slow speed stirrers and the milk is kept stirred to prevent separation of milk fat. The pasteurized milk is periodically tested.

The milk is packed in 3 sizes of bottles, viz. $\frac{1}{4}$, $\frac{1}{2}$, and 1 seer. The bottles are washed in 4 washing machines, each capable of washing and sterilizing 12,000 bottles per hour; it takes 20 minutes to clean one batch. The clean bottles travel on conveyors to the bottle filling machines. Empty crates are also washed and cleaned and conveyed to the filling machines. The bottles are filled in 8 vacuum operated machines, each capable of filling 70–100 bottles per minute according to size. The machines are so designed that

they do not fill broken or chipped bottles. They also make caps from aluminium strip and seal them on to the bottles. Each cap is coded so that it is possible to find out on what day and on which machines a particular bottle was washed and filled.

The filled bottles are kept under cold storage at c. 40°F. till they are taken out for distribution.

A part of the milk supplied to consumers in Bombay is processed in 4 small plants at Anand. It is now proposed to start a large dairy at Anand to replace the small, somewhat out-dated and uneconomic plants. The Bombay Milk Scheme now handles c. 3,000 md. of milk per day, and pasteurized milk is distributed through more than 700 centres in the city and suburbs. The value of milk so distributed amounts to nearly Rs. 2 crores per annum. Some 700 samples are analyzed daily to ensure that the milk supplied to consumers is of the proper quality.

Toned milk is also prepared in the dairy at Aarey, pasteurized, and filled in bottles. Toned milk is made by mixing 100 parts of buffalo milk, 100 parts of water, and 10 parts of skim-milk powder, to give a mixture containing

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approximately 3.5% fat and 9% solids-not-fat. One hundred maunds of buffalo milk give 160 md. of toned milk. The milk is pasteurized and filled into sterilized bottles. Plain aluminium caps are used for sealing the bottles.

A factory has been set up in Madras for the production of Reconstituted Milk for the use of low-income groups and catering establishments. The milk is produced by emulsifying a solution of separated milk powder with refined coconut oil. The milk produced is pasteurized by holding for half an hour at 140-150°F., passed through a homogenizer at a pressure of 1,500 lb./sq. in., cooled to 40°F., and bottled. Reconstituted milk is used in catering establishments for the preparation of tea and coffee, and its use has released a considerable quantity of fresh milk for consumption in households.

Quality, Composition and Standards.—The outstanding characteristic of the milk of Indian animals is its richness in fat. The average percentage of fat in cow milk is c. 4.5 and in buffalo milk, c. 6.0. Individual buffaloes may give milk containing 10-12% fat.

Table 29 gives the fat contents of cow milks in different countries.

TABLE 29—BUTTER FAT CONTENTS OF COW MILKS FROM DIFFERENT COUNTRIES*

| | Yield per lactation (lb.) | Av. butterfat content (%) | Yield of butterfat per animal (lb.) |
|-----------------|---------------------------|---------------------------|-------------------------------------|
| Punjab cows | 1,445 | 5.0 | 72 |
| do. buffaloes | 2,320 | 7.0 | 162 |
| Canadian cows | 4,408 | 3.8† | 167 |
| Australian cows | 4,802 | 3.8† | 182 |

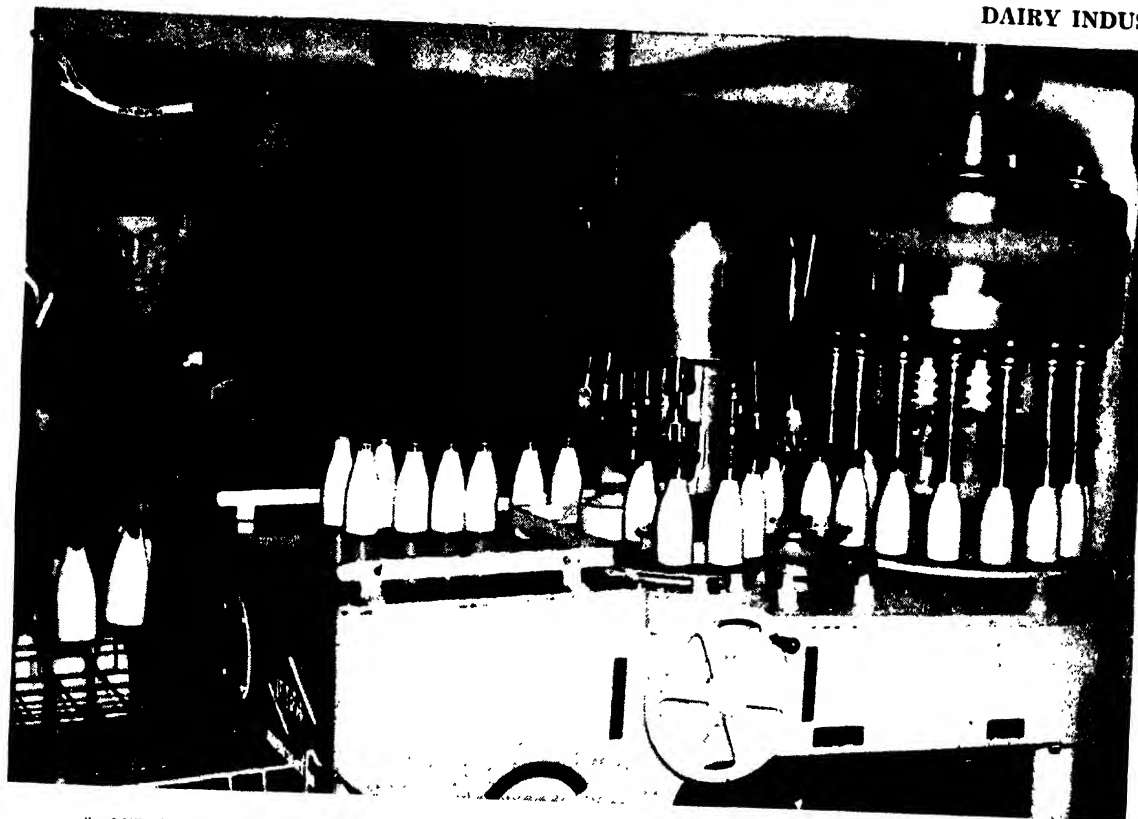
* *Rep. Marketing Milk*, 17

† Sometimes less



The Milk Commissioner, Bombay

FIG. 7—AUTOMATIC BOTTLE WASHING MACHINES HAVE BEEN INSTALLED IN THE DAIRY AT AAREY



8—AUTOMATIC BOTTLE FILLING AND SEALING MACHINES HAVE BEEN INSTALLED IN THE DAIRY AT AAREY *The Milk Commissioner, Bombay*

The buffalo is considered to be the most economical butter fat producing dairy animal in India. A comparison of the average composition of authentic milk samples from village animals and animals maintained in dairy farms has not revealed any striking difference in fat and solids-not-fat contents. Evening milk is as a rule richer in fat than morning milk, the difference varying from 0.5 to 1.0 unit. Table 30 gives the average composition of milks from Indian animals.

The data presented in Table 30 give only an approximate idea of the composition of milks. The analytical values are known to vary with the number of animals in the herd, feeds, physiological state of the animals, and other factors. The data show that buffalo milk is richer in fat, solids-not-fat, lactose, and nitrogen content than cow milk. Goat milk resembles cow milk in average composition, and sheep milk resembles buffalo milk. Compared to milks of other species, sheep milk is richer in vitamins.

Buffalo milk contains fewer but larger fat globules than cow milk. Milk from draught breeds



FIG. 9—COLD STORAGE IN THE DAIRY AT AAREY *The Milk Commissioner, Bombay*

DAIRY INDUSTRY

contain fat globules which are medium in size, more in number, and more uniform in shape than those present in milks from milch breeds. Among the milks of milch breeds themselves there is no marked variation in the number, size, or shape of fat globules. It has been observed that while

cow milk creams better at low temperatures (c. 50°F.), a higher temperature (70°-80°F.) is necessary for creaming buffalo milk.

The bacterial quality of market milk is poor. The fact that milk is invariably boiled before consumption has made the Indian consumer rather

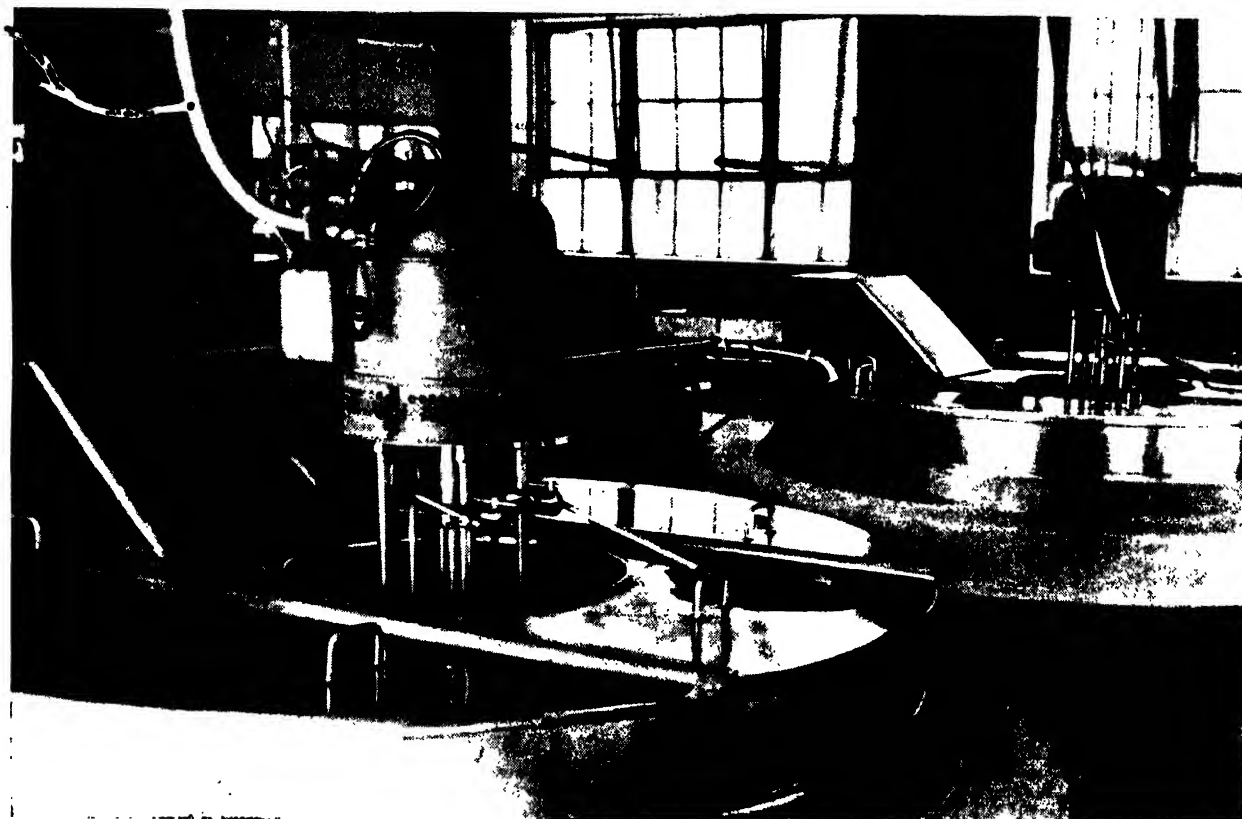
TABLE 30—COMPOSITION OF MILKS OF COWS, BUFFALOES, GOATS, AND SHEEP

| | Gir cows | Sahiwal cows | Sindhi cows | Thar- parkar cows | Cross-bred (Sindhi- Ayresshire) | Murrah buffalo | Goat | Sheep |
|--|-------------|-----------------|----------------|-------------------------|---------------------------------------|-------------------|--------|--------|
| Sp. gr. at 60°F. | 1.0301 | 1.0310 | 1.0305 | 1.0305 | 1.0304 | 1.0317 | 1.0317 | 1.0350 |
| Fat % | 4.73 | 4.35 | 4.80 | 4.55 | 4.50 | 6.56 | 4.50 | 6.04 |
| Total solids % | 13.34 | 13.34 | 13.52 | 13.21 | 13.13 | 15.93 | 13.46 | 16.15 |
| Solids-not-fat % | 8.62 | 8.79 | 8.72 | 8.66 | 8.63 | 9.37 | 8.96 | 10.11 |
| Lactose % | 4.82 | 5.01 | 4.92 | 4.84 | 4.90 | 5.32 | 4.68 | 4.99 |
| Chlorine % | 0.090 | 0.082 | 0.087 | 0.097 | 0.092 | 0.066 | 0.142 | 0.111 |
| Total nitrogen % | 0.520 | 0.521 | 0.536 | 0.526 | 0.529 | 0.609 | 0.547 | 0.759 |
| Casein nitrogen % | 0.400 | 0.400 | 0.409 | 0.406 | 0.406 | 0.472 | 0.467 | 0.610 |
| Albumin and globulin N % | 0.087 | 0.088 | 0.094 | 0.087 | 0.089 | 0.101 | 0.043 | 0.104 |
| Non-protein-nitrogen % | 0.033 | 0.033 | 0.033 | 0.033 | 0.034 | 0.036 | 0.037 | 0.045 |
| Crude protein % | 3.32 | 3.32 | 3.42 | 3.36 | 3.37 | 3.89 | 3.49 | 4.84 |
| Ash % | 0.66 | 0.66 | 0.70 | 0.68 | 0.67 | 0.72 | 0.77 | 0.81 |
| Citric acid % | 0.194 | 0.184 | 0.209 | 0.184 | 0.184 | 0.181 | 0.183 | 0.154 |
| Calcium (as CaO) % | 0.220 | 0.229 | 0.205 | 0.199 | 0.199 | 0.245 | 0.215 | 0.270 |
| Phosphorus (as P ₂ O ₅) % | 0.242 | 0.256 | 0.232 | 0.254 | 0.235 | 0.267 | 0.284 | 0.299 |
| Acidity (as lactic) % | 0.12 | 0.13 | 0.13 | 0.11 | 0.12 | 0.12 | 0.14 | 0.16 |
| Freezing point °C. | 0.549 | 0.546 | 0.549 | 0.549 | 0.548 | 0.549 | 0.579 | 0.589 |
| Vitamin A Blue units/100 cc. | 138.40 | 135.00 | 148.90 | 145.00 | 139.70 | 175.60 | 137.40 | 189.70 |
| Vitamin B group : | | | | | | | | |
| Thiamine µg/cc. | 0.54 | 0.43 | 0.50 | 0.48 | 0.45 | 0.50 | 0.43 | 0.97 |
| Riboflavin µg/cc. | 1.62 | 1.47 | 1.69 | 1.37 | 1.32 | 1.07 | 0.75 | 1.85 |
| Nicotinic acid µg/cc. | 0.81 | .. | 0.83 | 0.78 | 0.76 | 0.83 | 1.30 | 1.42 |
| Vitamin B ₁₂ µg/cc. | 0.90 | .. | 0.76 | 0.94 | .. | 0.72 | 0.85 | 14.00 |
| Vitamin C mg./cc. | 2.56 | 2.65 | 2.54 | 2.43 | 2.45 | 2.81 | 3.51 | 5.50 |

TABLE 31—STANDARDS FOR MARKET MILK IN DIFFERENT STATES

| | Minimum fat % | Minimum solids- not-fat % | Other specifications |
|---|---------------------|------------------------------------|---|
| <i>Buffalo milk</i> | | | |
| Assam, Bihar, Bombay, Hyderabad, & West Bengal | 6.0 | 9.0 | (a) Assam : sp. gr. ^{15.5°} , not less than 1.028 (b) West Bengal : sp. gr. ^{15.5°} , 1.028-1.030 minimum lactose, 4.4% |
| Madras, Mysore, & Travancore-Cochin | 4.5 | 9.0 | Minimum nitrogen, 0.53% |
| Madhya Bharat | 5.0 | 8.5 | |
| Delhi, Punjab, & Uttar Pradesh | 5.0 | 9.0 | Uttar Pradesh : sp. gr. ^{15.5°} , 1.028-1.030; minimum lactose, 4.0% |
| <i>Cow milk</i> | | | |
| Assam, Bihar, Bombay, Hyderabad, Punjab, Uttar Pradesh, & West Bengal | 3.5 | 8.5 | Assam : sp. gr. ^{15.5°} , not less than 1.028 West Bengal & U.P. : sp. gr. ^{15.5°} , 1.028-1.030 West Bengal : minimum lactose, 4.4% Uttar Pradesh : minimum lactose, 4.0% |
| Madras, Madhya Pradesh, Mysore, & Travancore-Cochin | 3.0 | 8.5 | Madras, Mysore, & Travancore-Cochin : minimum nitrogen, 0.50% |
| <i>Mixed milk</i> | | | |
| Bihar | 5.0 | 9.0 | Minimum lactose, 4.0% |
| Delhi & Madhya Bharat | 3.5 | 9.0 | |
| Punjab | 3.5 | 8.6 | |
| <i>Skimmed milk</i> | | | |
| Bombay & Uttar Pradesh | | 8.7 | |
| Madhya Pradesh | | 8.5 | |

These standards do not take into account the bacterial quality of milk



The Milk Condenser, Bombay

FIG. 10—MIXING MACHINES FOR PREPARING 'TONED MILK' IN THE DAIRY AT AAREY

indifferent to bacterial contamination of milk. The quality of milk produced in well organized dairy farms, e.g. in the farm of the Indian Dairy Research Institute, Bangalore, compares favourably with that of the highest grades of milk produced in U.S.A. or U.K. The bacterial counts of such milks are usually less than 10,000 per cc. and methylene blue reduction times exceed 6 hours. However, the same samples after exposure to the atmosphere for 3 to 6 hours show counts as high as 500,000 per cc. and methylene blue reduction times less than 4 hours. The poor quality of market milk is, therefore, attributed not only to the insanitary conditions of production and handling of milk, but also to the long exposure to tropical atmospheric temperature during transport and distribution. Coliform bacteria and *Streptococcus lactis* are mainly responsible for milk spoilage.

Cow milk and buffalo milk are usually mixed for sale. There is no organized attempt to supervise or regulate the production and marketing of milk in most areas. Some of the major municipalities have prescribed standards of quality, mainly with a view to check adulteration

with water which is widespread. These standards vary from place to place and are not enforced uniformly. Table 31 gives the legal standards prescribed for milk in different States under the Food Adulteration Act.

Marketing and Distribution—The total value of dairy products in India exceeds Rs. 350 crores. Imports during 1950-51 amounted to c. Rs. 462 lakhs, and exports, to Rs. 0.073 lakh.

About 18.7% or 900 lakh maunds of milk produced in the country enters the milk trade, 441 maunds in the form of fluid milk and the rest in the form of milk products. The bulk of the milk produced in rural areas is utilized locally.

In urban areas, 60-70% of the milk requirements is produced within the municipal limits; the rest is obtained from adjoining rural areas.

Only 6.0% of the total milk produced in the country is transported from rural to urban centres for consumption as milk and milk products. Nearly two-thirds of the milk received from outside the municipal limits comes from within five to ten miles of the towns, and the remaining one-third from beyond this distance. A part of the milk consumed in large cities, like Bombay, Calcutta,

DAIRY INDUSTRY

TABLE —WHOLESALE AND RETAIL PRICES OF MILK AT DIFFERENT CENTRES
(Price per maund in Rs. as. ps.)

| Wholesale price in | Bombay | Calcutta | Delhi | Kanpur | Madras | Amritsar |
|--------------------|---------|----------|---------|---------|---------|----------|
| 1939 | | 6 8 0 | 5 0 0 | 3 5 3 | 6 | 5 15 0 |
| 1942 | | 10 4 0 | 6 0 0 | 4 7 0 | 8 | 8 0 0 |
| 1945 | | 13 4 0 | 16 0 0 | 9 14 0 | 17 | 12 8 0 |
| 1948 | 35 2 7 | | 25 10 0 | 13 5 3 | | |
| 1949 | 40 10 8 | 36 6 7 | .. | | 25 0 0 | 23 4 |
| 1950 | 31 4 0 | 30 5 4 | .. | | 26 9 0 | 21 4 |
| Retail price in | | | | | | |
| 1943 | 74 10 8 | 38 5 4 | 30 0 0 | | 30 0 0 | 40 0 0 |
| 1949 | 43 5 4 | 40 13 4 | 30 0 0 | 27 1 4 | 27 14 8 | 27 14 8 |
| 1950 | 36 10 8 | 31 14 0 | 30 12 8 | 31 14 0 | 30 12 8 | 25 6 8 |

and Delhi, is obtained from localities situated at a distance of even 50 miles or more. About 500 maunds of chilled pasteurized milk are daily transported from Anand to Bombay, a distance of nearly 250 miles, in insulated rail vans.

Milk is commonly transported by head loads in brass, earthen or galvanized iron vessels and in tin cans. Bicycles, pack animals, tongas, and bullock carts are also used for transport. Only in a few instances are rail vans, motor lorries, and river transport utilized.

Most of the milk is distributed in towns by vendors twice daily—morning and evening. Raw milk is measured into customers' containers. Milk sold in bazaars may be raw, boiled, or boiled after sweetening.

Efforts have been recently initiated to organize the production and marketing of milk on a co-operative basis. There were in 1950, 28 milk unions with 549 affiliated primary societies, and 94 societies functioning in different regions of the country. Notable progress in co-operative dairying has been made in Madras, Uttar Pradesh, and Bombay.

Prices—Reliable data for estimating the cost of production of milk in India are scanty. A survey of records of Government farms in the Punjab, in 1931-32, showed that the average cost of production per lb. of milk was 8.58 pias for cow milk and 11.14 pias for Murrah buffalo milk. Another study in Madras State in 1945-48 showed that the cost of production varied from 36.2 pias to 55.13 pias per lb. The average cost at present can roughly be taken as 30 pias per lb. in rural areas and about 50 pias per lb. in urban areas.

The price of milk varies a great deal from place to place. In rural areas there is practically no market for fluid milk. The milk left over after meeting the demands of the producer's family is converted into butter, ghee, or *khoa*. These products are sold at weekly markets at prices largely determined by the distance of the markets from the towns.

As a rule, cow milk is cheaper than buffalo milk. Milk is cheaper in the northern and western

TABLE 33—UTILIZATION OF MILK IN INDIA*

| | Qty consumed (lakh md.) | Percentage of total production | Percentage of total milk products |
|-------------------------|-------------------------|--------------------------------|-----------------------------------|
| Fluid Milk | 1,740.96 | 36.2 | |
| Ghee | 2,065.16 | 43.3 | 67.8 |
| Dahi | 433.44 | 9.1 | 14.3 |
| Butter | 301.85 | 6.3 | 9.8 |
| Khoa | 199.50 | 4.1 | 6.5 |
| Cream | 29.63 | 0.6 | 1.0 |
| Ice-cream | 19.96 | 0.4 | 0.6 |
| Total | 4,815.50 | 100.0 | 100.0 |
| Rep. Marketing Milk, 53 | | | |

regions than in other parts. Some idea of the price of milk in urban areas may be had from the annual average figures for wholesale and retail prices of fluid milk at some important centres (Table 32).

Within the same area prices are higher during summer than in the monsoon season. It is estimated that about two-thirds of the retail price is received by the producer, the remaining one-third being shared by the middleman and the retailer. The price realized for ghee is 58%, for *khoa* 84%, and for butter 63% of the price of fluid milk.

Utilization—The bulk of milk produced in India is consumed as fluid milk and for the manufacture of ghee. Production is scattered over a wide area and the cost of collection and transport is prohibitive. Cow milk is preferred for consumption as milk and buffalo milk for the preparation of milk products. Table 33 gives the average annual consumption of milk for various purposes. Table 34 summarizes the available information on the utilization of milk for milk products in different States (*Agric. Marketing India, Brochure Marketing Milk, Brochure Ser., No. 3, 1949, 30*).

The average daily *per capita* consumption of milk in the Indian Union was estimated to be 5.45 oz. in 1945. Saurashtra tops the list with 18.78 oz. per head per day, followed by Punjab with 16.89 oz.; the consumption is lowest in Assam

TABLE 34—UTILIZATION OF MILK IN DIFFERENT STATES
(Qty in lakh md)

| | Total milk production | Used as fluid milk | Used for milk products | | | | Total | % used for milk products |
|-------------------|-----------------------|--------------------|------------------------|--------|--------|----------------|----------|--------------------------|
| | | | Ghee | Dahi | Butter | Other products | | |
| Assam | 26.48 | 15.01 | 6.67 | 1.43 | 1.25 | 2.12 | 11.47 | 43.32 |
| Bihar | 442.91 | 203.74 | 180.26 | 48.72 | 4.87 | 5.32 | 239.17 | 53.01 |
| Bombay | 318.86 | 105.83 | 163.81 | 28.20 | 12.16 | 8.86 | 213.03 | 65.28 |
| Madhya Pradesh | 108.93 | 12.96 | 87.15 | 1.63 | 6.75 | 0.44 | 95.97 | 88.10 |
| Madras | 576.90 | 184.61 | 299.99 | 86.54 | 3.46 | 2.30 | 392.29 | 68.00 |
| Orissa | 92.77 | 54.36 | 36.37 | 1.12 | .. | 0.92 | 38.41 | 42.36 |
| Punjab | 596.33 | 174.11 | 179.50 | 47.87 | 179.50 | 17.35 | 424.22 | 70.91 |
| Uttar Pradesh | 1,119.26 | 439.87 | 359.28 | 95.14 | 44.77 | 180.20 | 679.39 | 60.74 |
| West Bengal | 165.26 | 107.58 | 52.06 | 3.31 | 0.99 | 1.32 | 57.68 | 34.89 |
| Hyderabad | 164.91 | 38.75 | 109.67 | 7.92 | 3.79 | 4.78 | 126.16 | 76.54 |
| Jammu and Kashmir | 50.56 | 26.14 | 16.89 | 7.13 | 0.10 | 0.30 | 24.42 | 48.31 |
| Madhya Bharat | 143.58 | 55.57 | 66.76 | 15.79 | 0.72 | 4.74 | 88.01 | 61.30 |
| Mysore | 88.03 | 17.69 | 32.05 | 16.73 | 19.01 | 2.55 | 70.34 | 79.91 |
| PEPSU | 131.65 | 53.68 | 57.19 | 12.04 | 4.52 | 4.22 | 77.97 | 59.20 |
| Rajasthan | 240.01 | 54.81 | 162.39 | 15.52 | 2.60 | 4.69 | 185.20 | 77.18 |
| Saurashtra | 183.28 | 64.51 | 85.78 | 20.16 | 10.45 | 2.38 | 118.77 | 64.82 |
| Travancore | 22.51 | 8.62 | 12.50 | 1.35 | 0.02 | 0.02 | 13.89 | 61.72 |
| Delhi | 14.08 | 11.15 | 2.64 | 0.10 | 0.04 | 0.15 | 2.93 | 20.82 |
| Himachal Pradesh | 62.99 | 30.87 | 22.05 | 7.56 | 1.07 | 1.44 | 32.12 | 51.11 |
| Vindhya Pradesh | 33.22 | 14.35 | 14.02 | 3.32 | 0.47 | 1.06 | 18.87 | 56.79 |
| Other areas | 230.98 | 66.75 | 138.13 | 16.86 | 5.31 | 3.93 | 164.23 | 71.08 |
| Total | 4,315.50 | 1,740.96 | 2,085.16 | 438.44 | 301.85 | 249.09 | 3,074.54 | |
| % of total | | 36.15 | 43.30 | 9.11 | 6.27 | 5.17 | | 63.85 |

(1.2 oz.). Figures for other areas are : Rajasthan, 15.72; Baroda, 13.57; Madhya Bharat, 7.34; U.P., 7.16; and Delhi, 5.53 oz. The *per capita* consumption in other States is below 5 oz. (*Brochure Marketing Milk*, 31). The pre-war *per capita* consumption of milk and milk products in other countries was : Canada, 56.8; U.S.A., 45.6; Australia, 44.0; U.K., 40.7; and Denmark, 40.3 oz.

Future Prospects—The present retail prices of milk in urban areas in India are higher than those obtaining in most other countries. This is due, principally, to inadequate supplies. With a view to increasing the *per capita* consumption of milk, the Planning Commission has suggested the adoption of measures for raising milk production in suburban areas. Emphasis has been laid on the need for maintaining hygienic conditions during the collection, transportation, and distribution of milk and for enforcing measures of quality control.

The plan envisages 27 dairying and milk supply schemes, estimated to cost Rs. 779.3 lakhs. About 77% of the total expenditure, or Rs. 600 lakhs, is to be incurred in Bombay State for supplying milk to the cities of Poona, Hubli, and Ahmedabad. A sum of Rs. 50 lakhs has been earmarked by the Government of West Bengal for the removal of dairy cattle from Calcutta to the adjacent farm at Haringhata and for supplying standardized milk

to consumers in Calcutta city. The provision made in the plan for milk supply schemes in States other than Bombay is inadequate.

The Planning Commission has suggested the setting up of a statutory milk board for each urban area, consisting of representatives of producers, distributors, consumers, municipalities, health authorities, and the State Government. The board is required to survey the area under its jurisdiction and prepare a Milk Plan. Matters relating to handling, distribution, quality control, imports, and prices of milk and milk products will be dealt with by the board, which will be responsible for organizing milk production in suburban and urban areas through co-operatives. Financial assistance needed by the board and co-operatives will be provided by Government, municipalities, and co-operative banks. The board will also strengthen the machinery for licensing and sampling, and take steps to prosecute those who adulterate milk. Local standards for quality of milk and milk products, now in force in different urban areas, will have to be re-examined and revised to ensure satisfactory milk supplies to consumers. Village schemes have been formulated for improving the breeds of milch cattle and for ensuring adequate fodder supplies for dairy cattle.

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MILK PRODUCTS

A variety of milk products is known in India (Table 35) and some of them figure in inter-State trade. Dairy products, such as cheese, condensed milk, and milk powder, are not manufactured on any significant scale in India.

DAHI

Dahi is prepared by souring milk with a lactic acid starter. It is consumed as such or used in the preparation of butter. It is the Indian counterpart of Yogurt or Cultured Milk.

Dahi for direct consumption is prepared preferably from buffalo milk. The milk is first boiled and then cooled to c. 32°. A starter (usually dahi of the previous day) is added to the extent of 1-5%. The vessel containing the milk and the inoculum is kept near the kitchen fire, or wrapped with cloth, or placed in a pack of straw to keep it warm, particularly during the winter months. The curd is ready for consumption in 10-12 hours. Sugar is added if a sweetened product is desired. Butter fat tends to concentrate at the top layer, particularly when the milk is

curdled in shallow vessels. If the vessel is sufficiently shallow, over 90% of the fat collects in the top-quarter layer. A more uniform distribution of fat in the dahi is secured if the milk is kept stirred for 3 to 4 hours after inoculation, i.e. until coagulation begins.

Dahi contains 0.6-1.0% titratable acid expressed as lactic acid. It has a 'lactic flavour' and a compact smooth texture. Its composition varies with the quality of milk used, the type of organisms present in the starter, and the time allowed for souring. A sour product with a predominance of *Lactobacillus bulgaricus* is popular in south India. Dahi prepared in many parts of north India is less acidic and more aromatic; the organisms present in the dahi are mainly streptococci (*Streptococcus thermophilus* type) and *Lactobacillus casei*. Other lactic acid producers found in dahi are *Streptococcus faecalis*, *S. lactis*, *L. plantarum*, *L. helveticus*, *L. lactis* and *L. fermenti*.

The changes which occur during the preparation and storage of dahi are indicated in Table 36.

Dahi is normally consumed at the place of production. About 9.1% of the total milk produced in India, or 438.44 lakhs md., is converted

TABLE 35—INDIGENOUS MILK PRODUCTS

| Product | Uses | Yield (in lb.) per 100 lb. mixed milk | Related dairy product |
|--|---|---|---|
| <i>Bandal</i> (Beng.); <i>Paneer</i> (Hindi) | Direct consumption | 38 | Soft cheese |
| <i>Barie</i> (Hindi, Guj.); <i>Khavas</i> (Mar.); <i>Ginnu halu</i> (Kan.); <i>Si pal</i> (Tamil); <i>Gunnu palu</i> (Tel.) | Direct consumption | .. | Colostrum |
| <i>Channa</i> (Beng.) | Preparation of sweetmeats | 22 | Food casein |
| <i>Dacca</i> (Beng.) | Direct consumption | 10 | Hard cheese |
| <i>Dahi</i> (Hindi, Guj., & Mar.); <i>Dai</i> (Beng.); <i>Dadhi</i> (Guj.); <i>Mosuru</i> (Kan.); <i>Thairu</i> (Tam.); <i>Perugu</i> (Tel.) | Direct consumption and preparation of sweetmeats | 100 | Starters and fermented milk |
| <i>Ghee</i> (Hindi, Beng., Guj.); <i>Toop</i> (Mar.); <i>Thuppa</i> (Kan.); <i>Nai</i> (Tam.); <i>Neyyi</i> (Tel.) | Cooking and direct consumption | 5.3 | Clarified butter fat, dry butter, butter oil |
| <i>Kheer</i> (Hindi, Beng., Guj., Tam.); <i>Basundi</i> (Mar.) | Direct consumption | 15-20 | Condensed milk |
| <i>Khoa</i> (Hindi, Beng., Kan., Tel., Guj.); <i>Mava</i> (Guj.); <i>Khara</i> (Mar.); <i>Theratti</i> <i>Pal</i> , <i>Khoa</i> (Tam.) | Preparation of sweetmeats | 25 | Milk powder |
| <i>Khurchan</i> (Hindi) | Direct consumption | 15-20 | Condensed milk |
| <i>Kulfi</i> (Hindi, Guj.) | Direct consumption | 100 | Ice-cream |
| <i>Lassi</i> (Hindi); <i>Ghol</i> (Beng.); <i>Chhas</i> (Guj.); <i>Majjige</i> (Kan., Tel.); <i>Tak</i> (Mar.); <i>Moru</i> (Tam.) | Direct consumption | 175 | Butter-milk |
| <i>Makhan</i> (Hindi, Beng., Guj.); <i>Benne</i> (Kan.); <i>Loni</i> (Mar.); <i>Vennai</i> (Tam.); <i>Venna</i> (Tel.) | Direct consumption | 6.3 | Butter |
| <i>Malai, Sar</i> (Hindi, Beng., Guj.); <i>Kene</i> (Kan.); <i>Sai</i> (Mar.); <i>Adu, Adai</i> (Tam.); <i>Meegada</i> (Tel.) | Direct consumption | 20-25 | Clotted cream |
| <i>Malai-ka-Baraf</i> (Hindi) | Direct consumption | 100 | Ice-cream |
| <i>Rabree</i> (Hindi, Beng., Guj.) | Direct consumption | 25-30 | Condensed milk |
| <i>Surti paneer</i> (Hindi, Guj.); <i>Palkati</i> (Tam.) | Direct consumption | 38 | Soft cheese |

TABLE 36—COMPOSITION OF DAHI PREPARED FROM BOILED MILK

| | Sp. gr. ^{15.5°} | Fat % | Titrateable acidity (lactic acid) % | Lactose % | Ash % | Total nitrogen % | Protein nitrogen % |
|----------------------------|--------------------------|-------|-------------------------------------|-----------|-------|------------------|--------------------|
| <i>From buffalo milk :</i> | | | | | | | |
| Milk | 1.0375 | 6.7 | 0.14 | 5.47 | 0.72 | 0.64 | 0.60 |
| Dahi 24 hr. | 1.0307 | 4.5 | 1.69 | 3.27 | 0.72 | 0.64 | 0.59 |
| do. 72 hr. | 1.0289 | 4.5 | 1.89 | 1.76 | 0.72 | 0.64 | 0.57 |
| do. 48 hr. | 1.0300 | 4.5 | 1.85 | 1.70 | 0.72 | 0.64 | 0.56 |
| <i>From cow milk :</i> | | | | | | | |
| Milk | 1.0329 | 4.5 | 0.13 | 4.81 | 0.75 | 0.51 | 0.48 |
| Dahi 24 hr. | 1.0278 | 6.7 | 0.51 | 2.77 | 0.75 | 0.51 | 0.47 |
| do. 48 hr. | 1.0265 | 6.7 | 0.74 | 2.52 | 0.75 | 0.51 | 0.45 |
| do. 72 hr. | 1.0250 | 6.7 | 1.02 | 2.20 | 0.75 | 0.51 | 0.44 |

TABLE 37—STANDARDS FOR DAHI

| | Minimum fat % | |
|----------------|---------------|-------------------|
| | from cow milk | from buffalo milk |
| Bengal | 3.5 | 6.0 |
| Bombay | 3.5 | 6.0 |
| Madhya Pradesh | 3.0 | 5.0 |
| Uttar Pradesh | 3.5 | 3.5 |

into dahi. Table 37 gives the standards prescribed for dahi in different States.

CREAM

Cream is the fat-containing fraction separated from milk by centrifuging. The separator commonly employed consists of a bowl with a large number of conical discs arranged one above the other with intervening spaces. Milk enters through an opening in the centre and as the bowl is rotated (3,000–20,000 r.p.m.), the lighter fraction, which is cream, is driven towards the centre and the heavier fraction or skimmed milk is drawn towards the periphery and drawn out. The yield and the quality of cream vary according to the quality of milk and the speed of the separator. Skimmed milk, obtained as a by-product, contains 0.04–0.5% fat and is used in the manufacture of condensed milk, milk powder, butter-milk, and cheese. The yield of cream is about 10% from buffalo milk, 6% from cow milk, and 7.5% from mixed milk. No standards have been prescribed for cream. The percentage of fat in table cream varies from 20 to 30.

Cream production in India is confined to a few urban centres where table butter is in demand. The total annual production of cream is estimated to be 271,000 md. valued at Rs. 162.6 lakhs. Aligarh, Anand, and Patna are the chief centres of cream trade. Milk cans are used for carrying cream.

Various types of cream are manufactured in foreign countries. Light cream (fat, 18–30%), light whipped cream (fat, 30–36%), heavy whipped cream (fat, c. 36%), and plastic cream (fat, 65–83%) are well known. Aerated cream is obtained

by placing cream in a closed vessel containing carbon dioxide or nitrous oxide under pressure and subsequently releasing the pressure, when the cream swells up and the volume increases 6–8 fold. Canned sterilized cream retains its flavour and body for about 2 years (Getz *et al.*, *J. Dairy Sci.*, 1936, 19, 490).

BUTTER

Butter is a mixture of milk fat, butter-milk, and water; salt and colouring materials are often added. It is a good source of vitamin A and a fair source of vitamin D. The characteristic flavour of butter is due to diacetyl ($\text{CH}_3\text{-COCOCH}_3$) formed by the oxidation of acetyl methyl carbinol. Butter is characterized by spreadability, a characteristic not found in butter substitutes. This property is due to the glyceride structure of butter fat and to the presence of lower saturated fatty acids (Hilditch, 290).

Desi butter or *makhan* is prepared by churning dahi, after dilution with water, in earthen or tinned metal pots by a wooden pole, to one end of which beaters are attached. The curd breaks up and the separated fat collects on the surface in lumps. The butter thus separated is converted into ghee immediately, or it is stored submerged in water or butter-milk for several days before conversion into ghee. The fat separation is incomplete and as much as 25% of the milk fat remains in the butter-milk. A high recovery (c. 92%) of butter is obtained when sour curd, with an acidity (as lactic acid) of about 1.0% is diluted with an equal volume of water and churned within 24 hours after the addition of the starter to the milk. Desi butter is prepared in Bihar from *challi*, or the fatty layer which rises to the surface of dahi. *Challi* is collected for 2 or 3 days, water added, and the mixture churned to separate the butter (*Agric. Marketing India, Rep. Marketing Ghee & other Milk Products, Marketing Ser.*, No. 50, 1948, 48).

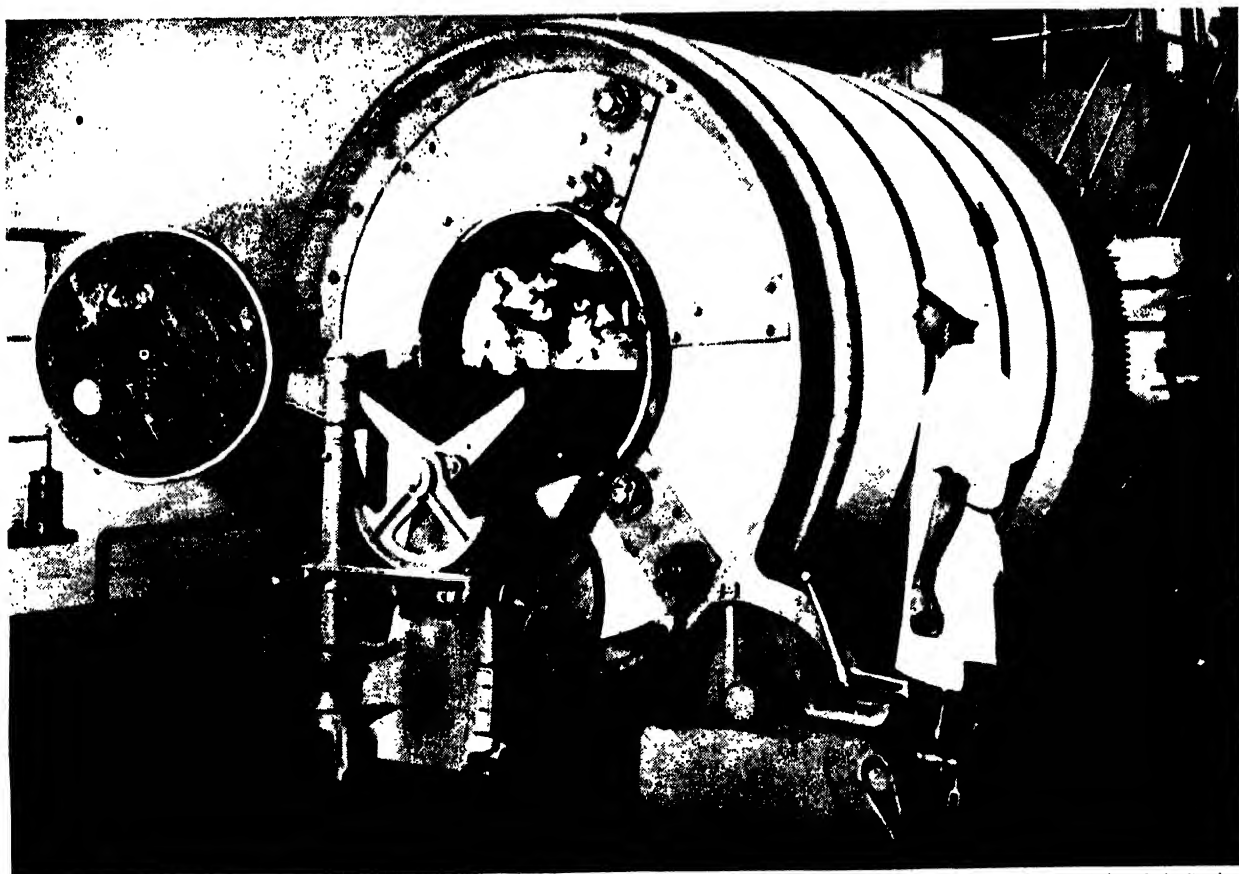
Desi butter usually contains 18–25% water and varying quantities of curd. It is not usually salted.

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The amount of milk utilized for preparing desi butter is estimated to be 641.5 million lb. Desi butter is produced principally in Punjab, Uttar Pradesh, Mysore, and Bombay.

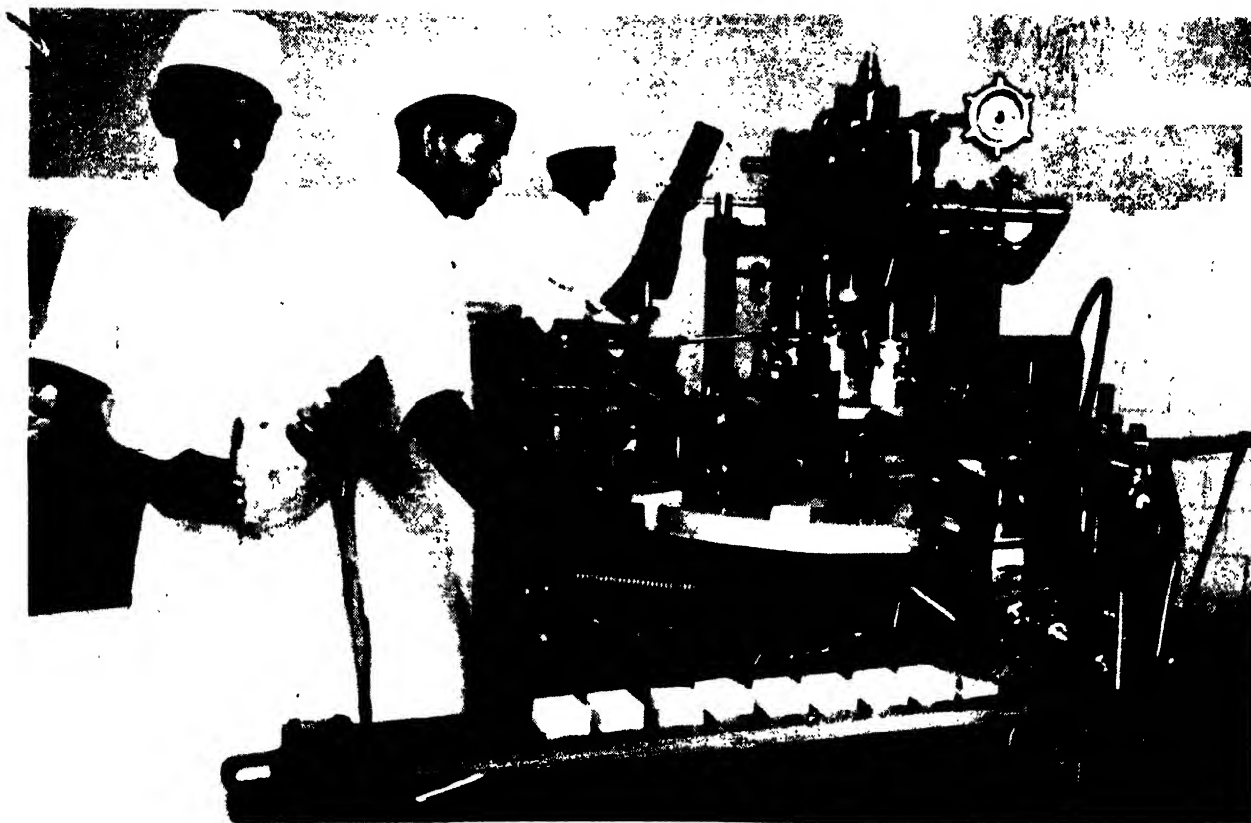
Creamery butter.—The production of creamery butter in India is confined to a few dairies at Anand, Aligarh, and other urban centres. The process employed in its preparation is as follows: cream is aerated and ripened at 75–95°F. to develop the desired aroma and to facilitate churning. The ripening is effected usually by the addition of natural starters, such as dahi, fermented cream, and butter-milk, or commercial starters containing pure cultures of lactic acid bacteria. Barrel churns of the end-over-end type mounted on horizontal supports and revolved by a handle are used for churning. The barrel is provided with a glass window for watching grain formation and a spring ventilator in the lid for the escape of gases. An outlet at the bottom allows butter-milk and wash water to be drawn off. The ripened cream, after dilution with cold water, is mixed with a small quantity of annatto

dye (from *Bixa orellana*) and charged into the churn to 1/3–1/2 its volume. The lid is fitted in and the barrel rotated. In the initial stages the ventilator is frequently lifted to allow gases to escape. The speed of rotation is reduced when graining begins and churning is stopped when butter lumps are formed. The temperature of the mix is maintained at 50–60°F. Churning is usually carried out in the mornings when the temperature is low, or ice is added to maintain the desired temperature. The whole operation takes 1/2–3/4 hr. Butter-milk is drained off and the butter washed repeatedly with cold water. It is then salted (up to 2.5%) by adding salt solution either in the churn or after scooping out the butter and working the mixture in a butter mix. Excess moisture is pressed out to give a product with a firm and compact texture and packed into bricks of varying sizes—7.5, 1, 1/2, and 1/4 lb. Weighing, moulding, wrapping, and packing are carried out by the use of machinery. In small-sized dairies, moulding is effected by warming the butter and shaping with a pair of scotch hands or by pressing in moulds.



Messrs. Polson Ltd., Bombay

FIG. 11—COMBINED BUTTER CHURN AND WORKER AT POLSON MODEL DAIRY, ANAND



Messrs. Polson Ltd., Bombay

TABLE —AUTOMATIC BUTTER PACKET WRAPPING MACHINE AT OLSON MODEL DAIRY, ANAND

The process employed in the Polson Dairy at Anand is as follows: the cream is aerated to remove off-flavours, neutralized if necessary with alkali (soda or magnesia), and flash pasteurized in a Vacreator at 200°F. The pasteurized cream is cooled to c. 50°F., ripened with a commercial starter culture for 4-6 hr., conditioned at 45-52°F. for 12-16 hr., and churned at 46-56°F. in power churns. Salt is then added (up to 2%) and the grains are kneaded by rollers inside the churns. The butter is conveyed to an automatic weighing platform, moulded, and packed in paper cartons or tin containers.

Continuous processes of butter manufacture have been developed and worked in many countries. In the New Way Process developed in Australia, flash pasteurized cream is pumped to a vat at 140°F. and salt and water added if necessary. The cream, which is an oil-in-water emulsion, is converted to butter by forcing through an extruder consisting of a pair of concentric hollow cylinders with square-cut threads geared in opposite directions. The cream enters through the annular space at one end and is forced

through the other. The product obtained is inferior to churned butter as it contains a higher proportion of curd and phospholipids. In the Fritz Process developed in Germany during World War II, cream containing 40-50% fat is pasteurized at 203°F., cooled to 45-50°F., and churned by high speed dashers for about 1½ sec. The butter granules are separated by the action of two inter-meshed screws rotating in opposite directions. The butter-milk is drained off and the butter forced through perforated plates. The final product contains 11-30% moisture. In the Alpha Process, butter is separated from cream by phase inversion. Milk pasteurized at 203°F. is passed through an air-tight cream separator to give a product containing 75-78% fat. The cream is cooled to 48-50°F. when phase reversal takes place. No butter-milk is produced in this process. The butter is warmed to about 57°F. for packing. In the Cherry-Burrel Process developed in U.S.A., the cream (86-90% milk fat) is continuously pasteurized at 190-200°F. in a vacuum pasteurizer or Vacreator, cooled to 110-115°F., and agitated with salt and water in vats. Colouring substances

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TABLE 38—STANDARDS FOR BUTTER IN DIFFERENT STATES

| | Type of butter | Maximum moisture | B. R. index | Reichert val. | Sap. val. | Remarks |
|----------------|----------------|------------------|-------------------|---------------|-----------|--|
| | | | not less than : | | | |
| Assam | Cow | 20 | | 24 | 222 | Must be exclusively derived from milk or cream (other than condensed, sterilized or desiccated milk or cream) or both, with or without the addition of colouring matter of such a nature and in such quantity as not to render the article injurious to health |
| | Buffalo | 20 | | 30 | 224 | |
| | Mixed | 20 | | 28 | 228 | |
| Bihar | | 16 | 40-42 (at 40°) | | | Boric acid or borax, as preservative, shall not be added in a greater proportion than 0.5% |
| Bombay | | 20 | | | | Must be prepared exclusively from milk or cream of cow or buffalo or both, with or without the addition of common salt |
| Madras | | 20 | | | | Must be prepared from milk or cream or both, with or without the addition of salt or other innocuous preservative or of innocuous colouring matter |
| Madhya Pradesh | .. | 16 | 40-46 (at 40°) | 19-36 | .. | |
| Punjab | .. | 16 | .. | .. | .. | Must be made exclusively from milk of cow or buffalo; not less than 80% of the butter must be milk fat |
| Uttar Pradesh | Cow | 16 | 48-51 (at 25°) | 24 | 220 | Must be made exclusively from milk or cream or both, with or without the addition of salt and with or without the addition of vegetable colouring matter |
| | Buffalo | 16 | 48-51 (at 25°) | 30 | 220 | |
| | Mixed | 16 | 48-51 (at 25°) | 28 | 220 | |
| West Bengal | .. | 20 | .. | .. | .. | Must be made exclusively from milk or cream (other than condensed or desiccated milk or cream) or both, with or without the addition of (vegetable) colouring matter |

TABLE 39—AGMARK SPECIFICATIONS FOR TABLE BUTTER

| Grade designation | Special characteristics | General characteristics |
|---------------------------------|---|--|
| Select table butter | Shall be made from raw cream; the product shall be of reasonably good keeping quality and show no appreciable signs of deterioration in flavour if retained at 80°F. for 3 days | (a) Shall be derived only from clean, fresh, and wholesome cream obtained from the milk of cows or buffaloes, or both, with or without the addition of clean dairy salt (not exceeding 2%) and harmless colouring matter; the butter shall contain no preservative |
| Select pasteurized table butter | Shall be from pasteurized cream; the product shall be of good keeping quality and show no appreciable sign of deterioration in flavour if retained at 80°F. for 15 days | (b) Flavour: clean, pleasant, and free from objectionable taint or rancidity (c) Texture: should be firm at 60°F., neither greasy nor oily, and show a granular surface on breaking (d) Colour: even, without streakiness, mottling, stains, or signs of curd (e) Moisture, not more than 16% |

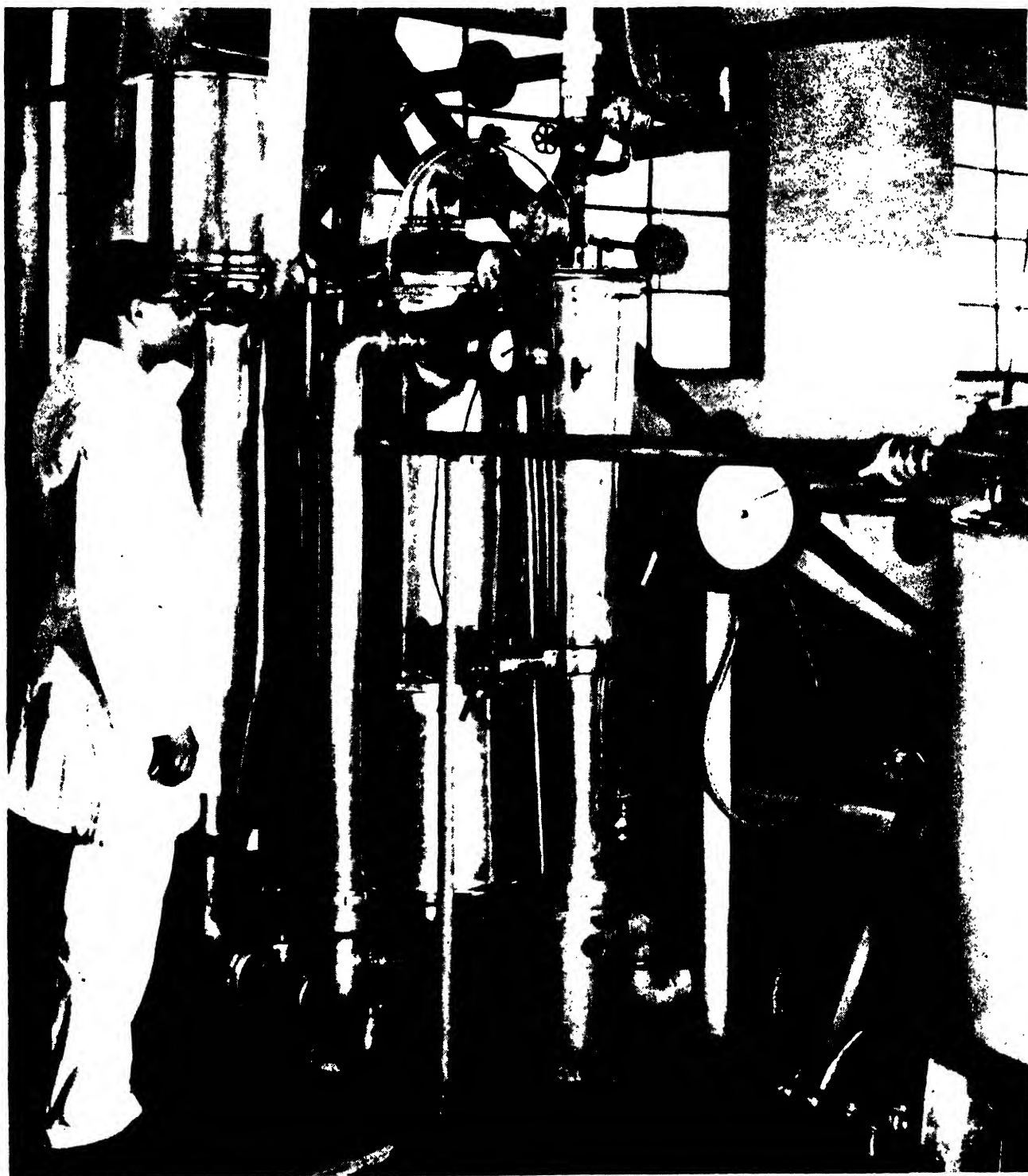
TABLE 40—WHOLESALE AND RETAIL PRICES OF BUTTER

| | (Price per lb. in Rs. as. ps.) | | | |
|------|--------------------------------|----------|--------|----------|
| | Wholesale | | Retail | |
| | Bombay | Calcutta | Bombay | Calcutta |
| 1942 | 1 6 0 | 1 8 0 | 1 7 3 | 1 7 0 |
| 1945 | 2 0 0 | 2 3 0 | .. | .. |
| 1948 | 2 6 0 | 3 0 0 | .. | .. |

and neutralizers may be added if necessary. The mixture is pumped under pressure through a

chilling unit (40°F.) and partially washed. It is further worked in a Texturator, extruded, cut, and wrapped (Hills, *Aust. J. Dairy Tech.*, 1946, 1, 43; Gemmill, *Food Ind.*, 1946, 18, 841, 996, 998; Lampert, 181).

The annual production of creamery butter in India is c. 222,000 md. The standards prescribed for butter are given in Table 38. Standards for butter fat have been prescribed only in some States; in other States, the standards given under ghee hold good for butter also.



Messrs. Polson Ltd., Bombay

VACREATOR FOR VACUUM PASTEURIZATION OF CREAM

Butter is graded under the AGMARK scheme according to standard specifications reproduced in Table 39.

Table 40 gives the average (annual) wholesale and retail prices of butter at some important centres.

GHEE

Ghee or clarified butter is obtained from butter by eliminating water. It is next to milk in importance as a dairy product. It can be stored over long periods and for this reason it is preferred to butter in all tropical countries.

Ghee is produced in India according to the traditional process involving sour curdling of milk, recovering butter, and heating the butter to remove water. Desi butter is preferred to creamery butter as the ghee obtained from the former has better aroma and appearance.

Desi butter is melted into ghee at once or after storage up to 10 days. It may be partially dehydrated and later converted into ghee according to market demand.

For direct conversion into ghee, butter is briskly heated and the scum formed removed by a ladle from time to time. Heating is stopped when effervescence ceases; the sediment of curd begins to turn brown and a characteristic aroma develops. The pot is removed from the fire, suspended matter allowed to settle, and the clear ghee decanted into tin containers or earthen pots.

The temperature employed for clarifying butter varies from 80° to 125°. The temperature influences the flavour of ghee. The product obtained by heating to temperatures exceeding 115° has a burnt flavour and is preferred in certain parts of the country. Short exposure to 120° does not interfere with grain formation, nor does it diminish the carotene and vitamin A contents of the ghee. A lower temperature is employed for clarifying butter containing a high percentage of free fatty acids.

For preparing ghee from creamery butter, the latter should be desalted before clarification. The use of creamery butter for ghee making is uneconomical and the usual practice is to clarify cream directly. This method is widely followed in some parts of Bihar, particularly in Monghyr and Darbhanga districts. The cream is heated in the same manner as butter when it breaks up. The fat which collects on the surface is transferred to another vessel and heated to about 115° to remove moisture.

The product obtained from sweet cream does not possess the flavour characteristic of ghee made from desi butter; it is therefore advisable to sour the cream, which incidentally helps the separation of fat from curd and so gives a higher yield of ghee. The process is briefly as follows: Cream contain-

ing 60% or more fat is prepared by passing milk warmed to 37.8° through centrifugal separators. It is diluted with water to twice its volume and re-separated. The cream is inoculated with a starter, soured for 6-8 hours at 50°F., and then converted to ghee.

Small quantities of ghee are also produced directly from cream by a process developed in Tanganyika. Cream is diluted with half its volume of water and churned in a cream separator. The purified cream is heated until clear. The product is practically colourless and is solid below 85°F. It is free from rancidity and possesses good keeping qualities. The vitamin A content is reported to be three times that of ghee prepared by the traditional process.

Kachha ghee obtained from different sources is processed in central refineries to produce blends to suit particular markets. The mixture is heated at 80°-85° to eliminate moisture and to separate the suspended matter. The ghee is allowed to settle either in the melting tank or in separate settling tanks with taps fixed a little above the bottom. Two to three hours are allowed for settling and when the temperature falls to c. 60°, the clear melt is tapped off into tins.

To ensure proper grain formation, the tins to which ghee at 60° is transferred should be kept undisturbed and cooling allowed to take place gradually. Grain formation starts at c. 40° at the sides and granulation proceeds inwards. Ghee containing fine grains (*Lissoo Ghee*) is obtained by mixing ghee at c. 40° with seeding ghee and cooling. A product without grains and with a greasy appearance is prepared at Hathras (Uttar Pradesh). After refining the ghee and settling, an aliquot (9-10%) of the clear supernatant liquid is drawn off and rapidly cooled under water with vigorous stirring, while the rest is cooled gradually. The two are mixed together under stirring and the mixture transferred to containers and vigorously shaken.

Ghee is packed in 4-gallon tins holding about 36 lb. of ghee. Smaller containers of 20, 14, 10½, 7, 5½, 3½, and 1½ lb. capacity are also used.

Ghee as purchased in the market usually contains free fatty acids, previously present in butter and produced as a result of bacterial and mold action on butter fat. Acidity also develops during the storage of *kachha* ghee. Acidity up to 2.5% oleic acid is permitted in the trade. When the acidity exceeds this concentration, the ghee is treated with finely ground dehydrated lime (3%) and heated to 108°. The ghee which separates out as the top layer is tapped off.

In the preparation of ghee in households, it is usual to add a few leaves of betel (*Piper betel*) or small quantities of spices towards the close of the boiling period. It has been recently shown

TABLE 41—CHARACTERISTICS OF GHEE OBTAINED FROM MILKS OF DIFFERENT BREEDS OF ANIMALS

| Analytical Constants | Cross bred (Ayrshire-Sindhi) cow | Gir cow | Sahiwal cow | Sindhi cow | Tharparkar cow | Observed range of variations for cow ghee | Murrah buffalo | Observed range of variations for buffalo ghee | Surti goat | Kathiawar sheep |
|---|----------------------------------|---------|-------------|------------|----------------|---|----------------|---|------------|-----------------|
| Butyro-refractometer (B.R.) index (40°) | 43.03 | 43.10 | 42.90 | 42.85 | 43.05 | 42.1-47.7 | 42.04 | 40.9-46.9 | 42.60 | 43.40 |
| Reichert val. | 27.26 | 26.42 | 26.60 | 27.00 | 29.20 | 16.9-30.5 | 32.54 | 15.5-39.9 | 26.35 | 32.82 |
| Polenske val. | 1.75 | 1.72 | 1.80 | 1.70 | 1.94 | 0.9-3.2 | 1.41 | 0.4-5.3 | 5.30 | 2.67 |
| Kirschner val. | 22.70 | 21.80 | 22.00 | 21.33 | 25.70 | 14.0-27.5 | 28.52 | 12.0-37.0 | 19.96 | 26.93 |
| Sap. val. | 227.00 | 227.10 | 227.30 | 227.18 | 230.30 | 212.8-232.8 | 230.09 | 198.0-239.3 | 229.30 | 231.60 |
| Iod. val. | 33.60 | 33.50 | 33.20 | 32.80 | 33.90 | 28.4-40.6 | 29.40 | 21.4-39.9 | 35.10 | 36.04 |
| Colour (Lovibond yellow units/g.) | 9.00 | 9.00 | 8.00 | 8.40 | 9.50 | 4.3-13.4 | 0.80 | 0.3-1.8 | 1.10 | 1.40 |
| Vitamin A (I.U./g.) | 24.20 | 22.57 | 22.76 | 23.11 | 21.89 | 14.2-31.0 | 21.90 | 16.3-28.4 | 23.91 | 23.89 |

that additives, such as red chilli, cinnamon leaf, turmeric, clove, black pepper, nutmeg, betel leaf, and dry ginger, contain fat-soluble antioxidants which check the development of rancidity and enhance the keeping quality of the product. The additives also impart colour and flavour to the product. A special variety of red earth is occasionally added to obtain clear ghee. It is the practice in some localities to add a lump of salt during storage as it is believed to improve the keeping quality (Sethi & Aggarwal, *J. sci. industr. Res.*, 1952, **11B**, 486). 38. 365

The appearance of ghee—colour and grain structure—influences its market value. Cow ghee is yellow and buffalo ghee is white with a greenish tinge. The grains in buffalo ghee are bigger and harder than those in cow ghee. The flavour of ghee is also a criterion in determining the market value. The buyer judges this by rubbing a small quantity on the back of the palm, when due to the mild heat of the body the ghee melts and its aroma becomes perceptible.

Buffalo ghee is in demand in Bombay, Madhya Pradesh, Punjab, and Uttar Pradesh. Cow ghee commands a premium in Bengal, Madras and Rajasthan. Ghee prepared from the milks of goats and sheep is not sold in the market. Goat ghee has an unpleasant flavour and when added either to cow or buffalo ghee, the market value of the latter is lowered. A variety of ghee produced in Mehsana district (Bombay State), known in the trade as Yellow Ghee or *Bakaria* Ghee, is a mixture of cow, buffalo, goat and sheep ghees. It is used in the preparation of sweetmeats.

The composition of ghee varies according to the composition of milk from which it is derived. In certain areas the composition has been observed to vary with the season. Within the same breed, the food of the animal influences the composition of milk and hence the composition of ghee.

Table 41 gives the analytical constants of ghee from milks of different breeds of animals. Separate standards are usually prescribed for cow and buffalo ghees in different localities (Tables 42 & 43).

Cow ghee has a comparatively low Reichert value and a high butyro-refractometer (B.R.) index. Buffalo ghee has high Reichert value and low B.R. index, while sheep ghee has high Reichert value and high B.R. index. Both goat and sheep ghees have high Polenske values. Cow ghee contains carotene as well as vitamin A. The former is responsible for the yellow colour. Buffalo, goat, and sheep ghees are poor in carotene. The average total vitamin A potency of fresh ghee varies from 24 I.U. to 32 I.U. per gram.

Ghee is mainly used for cooking and frying. Its chemical composition undergoes little change when heated to the frying temperature (200–250°).

Ghee is subjected to extensive adulteration in the trade. The detection of adulteration is rendered difficult on account of the considerable variation in the composition of the genuine product in different seasons and in different localities. The most common adulterant of ghee is hydrogenated vegetable oil whose detection has been simplified as a result of the latest Control Order issued by the Vegetable Products Controller (*Gazette of India*, Oct. 21, 1950, S.R.O., 780), according to which hydrogenated vegetable oil shall contain not less than 5% by wt. of raw or refined sesame oil. Sesame oil can be readily detected by the Baudouin test [6–8 drops of 2% alcoholic furfural solution are added to 10 cc. of a 1:1 mixture of the adulterated ghee sample and hydrochloric acid (sp. gr., 1.19) in a test tube and shaken; a red colour is produced if the ghee sample is adulterated with hydrogenated oil and the colour persists even after 10 minutes

TABLE 42—STANDARDS FOR GHEE

| | Maximum moisture content % | B. R. index at 40° | Reichert val. | Sap. val. | Other specifications |
|---------------------------------------|-------------------------------------|-----------------------|------------------|-----------|--|
| <i>Cow Ghee</i> | | | | | |
| Agmark (Yellow label) | 0.5 | 40.5-42.5 | 26-28 | | Phytosteryl acetate, Baudouin, and phenolphthalein tests should be negative; Polenske val., 1.5-2.5; Kirschner val., 20-25; free fatty acids, not more than 1.5% oleic |
| Assam | .. | 40.0-42.5 | ≤ 24 | ≤ 222 | |
| West Bengal | .. | 40.0-42.5 | do. | ≤ 220 | |
| Bihar | .. | 40.0-42.0 | do. | | Phytosteryl acetate test should be negative |
| Orissa | .. | 40.0-42.0 | do. | | .. |
| Uttar Pradesh | 1.0 | 48.0-51.0 at 25° | do. | ≤ 220 | Free fatty acids, not more than 2.8% oleic |
| <i>Buffalo Ghee</i> | | | | | |
| Agmark (Blue label) | 0.5 | 40.0-42.5 | ≤ 30.0 | | Phytosteryl acetate, phenolphthalein, and Baudouin tests should be negative; Polenske val., 1.0-1.75; Kirschner val., not less than 25; free fatty acids, not more than 1.5% oleic |
| Assam | .. | do. | do. | ≤ 224 | |
| West Bengal | .. | do. | do. | ≤ 222 | |
| Bihar | .. | 40.0-42.0 | do. | .. | Phytosteryl acetate test should be negative |
| Orissa | .. | 40.0-42.5 | do. | .. | .. |
| Uttar Pradesh | 1.0 | 48.0-51.0 at 25° | do. | ≤ 220 | Free fatty acids, not more than 2.8% oleic |
| <i>Mixed Ghee</i> | | | | | |
| Agmark (Red label) | 0.5 | 40.5-42.5 | ≤ 28.0 | .. | Phytosteryl acetate, phenolphthalein, and Baudouin tests should be negative; Polenske val., 1.0-2.0; free fatty acids, not more than 2.5% oleic |
| Agmark (Green label; General quality) | 0.5 | 40.0-42.5 | do. | .. | |
| Ajmer-Merwara | .. | 40.0-44.5 | 21.0-32.0 | .. | Free fatty acids, not more than 2.8% oleic |
| Assam | .. | 40.0-42.5 | ≤ 28.0 | ≤ 224 | |
| West Bengal | .. | do. | do. | ≤ 222 | |
| Bihar | .. | 40.0-42.0 | do. | .. | Phytosteryl acetate test should be negative |
| Bombay | .. | 40.0-44.5 | ≤ 24.0 | .. | .. |
| Coorg | 1.0 | .. | ≤ 28.0 | .. | Provided that a sample of ghee or butterfat should not be presumed to be genuine solely by reason of the fact that it gives a Reichert val. of 28 or more |
| Delhi | .. | 40.0-43.5 | ≤ 24.0 | | Free fatty acids, not more than 2.5% oleic |
| Indian Army Service Corps (Blended) | .. | 40.5-42.5 | ≤ 28.0 | | Polenske val., 1.4-2.4; free fatty acids, not more than 2.5% oleic |
| Madras | 1.0 | | ≤ 28.0 | | Provided that a sample of ghee or butterfat should not be presumed to be genuine solely by reason of the fact that it gives a Reichert val. of 28 or more |
| Madhya Pradesh | .. | 40.0-46.0 | 19-36 | | |
| Orissa | .. | 40.0-42.5 | ≤ 28.0 | | |
| Punjab | .. | do. | ≤ 24.0 | | |
| Uttar Pradesh | 1.0 | 48.0-51.0 at 25° | ≤ 28.0 | ≤ 220 | Free fatty acids, not more than 2.8% oleic |

DAIRY INDUSTRY

standing] (Subramanyan *et al.*, *J. sci. industr. Res.*, 1952, 11A, 277; *Misc. Bull. I.C.A.R.* No. 64, 1946, 9).

The by-product of ghee refining is the ghee residue, left after decanting off the clear butter fat. It contains: moisture, 10-20; fat, 18-30; and other milk solids, 55-70%. The residue from ghee prepared under careful conditions is suit-

able for use in sweetmeat preparations. In actual practice, however, it is unfit for human consumption. It may be reclarified and a further quantity of ghee extracted from it for use as cattle feed or for soap making.

Ghee is produced throughout the country, and there is a considerable volume of inter-State trade in this product (Table 44).

TABLE 43—SPECIAL REGIONAL AGMARK STANDARDS FOR GHEE

[Phytosteryl acetate, phenolphthalein and Baudouin tests should be negative]

| | Maximum moisture content % | B. R. index at 40° | Reichert val (min.) | Sap. val. | Polenske val. | Free fatty acids as oleic (max. %) |
|---|----------------------------|--------------------|---------------------|-----------|---------------|------------------------------------|
| Applicable to Porbander (Kathiawar), Nawalnagar, and Junagadh States and Dhari and Khamba areas of Bombay State | | | | | | |
| August-December | 0.5 | 43.0-44.0 | 23 | 215-225 | 0.75-1.5 | 1.5 |
| December-April | do. | 43.0-44.5 | 19 | 212-220* | 0.5-1.0 | do. |
| April-August | do. | 44.0-45.0 | 17 | 210-215** | do. | do. |
| Cotton tract area (Madhya Pradesh) | do. | 42.0-44.0 | 20 | 215-230 | 0.5-1.5 | do. |
| Ajmer-Merwara | do. | 42.5-44.0 | 22 | 215-225 | do. | do. |

*Sap. val. up to 224 permissible, provided the Reichert val. is not less than 20

**Sap. val. up to 220 permissible, provided the Reichert val. is not less than 19

TABLE 44—INTER-STATE TRADE IN GHEE (RAIL & RIVER-BORNE)

(Qty in md)

| | Imports | | | Exports | | |
|--------------------------------------|---------|---------|---------|---------|---------|---------|
| | 1948-49 | 1949-50 | 1950-51 | 1948-49 | 1949-50 | 1950-51 |
| Assam | 524 | 187 | 544 | .. | .. | 5 |
| Bihar | 8,872 | 8,725 | 9,462 | 2,989 | 1,450 | 628 |
| Bombay | 37,964 | 20,155 | 19,985 | 32,784 | 15,362 | 16,267 |
| Madhya Pradesh | 840 | 1,208 | 521 | 985 | 1,252 | 2,265 |
| Madras | 19,540 | 12,254 | 12,261 | 39,497 | 75,277 | 61,404 |
| Orissa | 3,856 | 6,236 | 5,772 | 197 | 847 | 7 |
| Punjab | 1,300 | 1,204 | 3,337 | 7,474 | 13,824 | 10,272 |
| Uttar Pradesh | 7,754 | 5,779 | 2,009 | 8,020 | 8,801 | 25,045 |
| West Bengal | 25,863 | 37,963 | 54,958 | 3,925 | 5,785 | 1,684 |
| Hyderabad | 130 | 23 | 29 | .. | 313 | 133 |
| Jammu & Kashmir | .. | .. | 14 | .. | .. | 1 |
| Madhya Bharat | | | | | | |
| (Including Vindhya Pradesh & Bhopal) | 512 | 207 | 464 | 15,648 | 2,380 | 2,619 |
| Mysore | 300 | 23,192 | 698 | 167 | 402 | 47 |
| Rajasthan | 4,880 | 1,282 | 2,801 | 1,570 | 1,188 | 990 |
| Delhi | 1,505 | 9,196 | 9,106 | 584 | 730 | 594 |
| Total | 113,840 | 127,611 | 121,961 | 113,840 | 127,611 | 121,961 |



STEAM GHEE BOILER

Messrs. Polson Ltd., Bombay

TABLE 45—WHOLESALE PRICES OF GHEE AT DIFFERENT CENTRES

| | (Price per md in Rs. as. ps.) | | | | | | |
|------|-------------------------------|-----------|----------|---------|---------|------------|----------|
| | Calcutta | Jullundur | Khurja | Madras | Patna | Shikohabad | Tiruppur |
| 1938 | 51 10 9 | 44 2 9 | 42 0 0 | .. | 41 15 3 | .. | 42 13 0 |
| 1942 | 81 14 9 | 72 2 9 | 62 11 0 | .. | 48 11 9 | .. | 69 15 0 |
| 1945 | 180 0 0 | 152 13 0 | 133 1 9 | .. | 120 0 0 | .. | 127 3 0 |
| 1948 | 229 6 7 | 260 0 0 | 211 0 0 | 208 1 7 | .. | 202 14 0 | 169 9 0 |
| 1949 | 206 6 10 | .. | 189 0 0 | .. | .. | 153 4 4 | 172 1 0 |
| 1950 | 208 9 8 | .. | 194 13 4 | .. | .. | 191 9 4 | 177 0 0 |

Ghee is imported into India from Arabia by sea, and from Tibet, Nepal, Sikkim, and Bhutan across land frontiers. The imported product is of inferior quality and is mostly used in confectionery.

Table 45 gives the wholesale prices of ghee at different centres.

LASSI

Lassi is the fluid obtained in the manufacture of desi butter from soured whole milk. It is relished as a cooling beverage, especially during hot weather, and consumed as such or after adding salt, spices, or sugar. It is richer in fat than creamery butter-milk. As a result of the aeration of dahi during the churning process, oxidation of acetylmethylcarbinol to diacetyl is favoured and the resulting lassi has a rich flavour. The approximate composition of lassi is as follows: water, 90-91; fat, 0.1-1.0; protein, 3.3-3.5; lactose, 2.5-3.5; ash, 0.7; and lactic acid, 0.5-1.1% (Davies, 32).

MALAI OR SAR

When milk is heated, a layer of fat and coagulated proteins, *Malai*, forms on the surface. Slow heating helps to increase the thickness of the layer. The volume of malai can be increased by boiling the milk until a voluminous froth is formed and cooling slowly over a dying fire. Buffalo milk, which is rich in fat, gives a thick layer of malai with little tendency to oil off. Malai is either consumed directly, or used in the preparation of sweetmeats. It has the following composition: moisture, 60-70; fat, 25-30; proteins, 3.0-3.5; lactose, 3.3-3.8; and ash, 0.4-0.5%.

CONDENSED MILK

Condensed milk is not produced in the country. During World War II, however, this product was

manufactured from buffalo milk for the use of Armed Forces. A few indigenous products, *Kheer*, *Rabree* and *Khurchan*, resemble condensed milk in composition.

Condensed milk is an important commercial product in U.S.A. and Europe. It is obtained by evaporating milk at 130°-135° in a vacuum pan to the required concentration. The concentrate is homogenized to prevent the separation of fat, cooled, and fortified if necessary. Stabilizers, such as disodium hydrogen phosphate or calcium chloride, are added in predetermined quantities to prevent coagulation during the sterilization. The product is filled into cans which are sealed, sterilized, agitated in a shaker for ensuring a smooth texture, and packed for the market. Sweetened condensed milk is obtained by concentrating milk, after adding sugar, in a vacuum evaporator at 120°F. to the required density. The condensed product is cooled rapidly to 80-86°F. and held at that temperature for 15-20 minutes. The milk is seeded with a small amount of sweetened condensed milk when lactose crystallizes out. Cooling is so controlled that the crystals are of small dimensions and remain in suspension in the viscous liquid.

Kheer is prepared by concentrating milk with vigorous stirring to one-third or one-fourth of its volume, by heating directly over a fire in open shallow vessels. The resulting viscous liquid is consumed as such or after sweetening. The product is homogeneous as a result of the vigorous stirring employed and it is consumed soon after preparation. The approximate composition of *kheer* is shown in Table 46.

Rabree is prepared by concentrating whole milk in round-bottomed iron vessels over direct fire. The milk is not stirred, but the surface is gently fanned to facilitate the formation of the skin of coagulated milk. The surface skin is broken into

TABLE 46—COMPOSITION OF KHEER

| Kheer from : | Moisture | Total solids | Fat | Lactose | Sucrose | Proteins | Ash |
|--------------------------|----------|--------------|------|---------|---------|----------|-----|
| Cow milk (sweetened) | 53 | 47 | 12.5 | 13.1 | 15-20 | 10.0 | 2.0 |
| Buffalo milk | 49 | 51 | 19.5 | 16.5 | .. | 12.5 | 2.5 |
| Buffalo milk (sweetened) | 49 | 51 | 15.6 | 15.7 | 15-20 | 10.3 | 2.0 |

flakes, c. 1½ in. square, with a bamboo splint and removed to the side of the pan above the level of the boiling milk. When the milk reaches the desired consistency, sugar is added (1 oz. per lb. of milk) and the flakes collected on the sides are submerged in it. Boiling is continued for a few minutes and the vessel removed from the fire. Rabree is usually prepared in batches starting with 5-6 lb. of milk. Slow heating gives thick creamy flakes and the finished product has a honey-like consistency. Buffalo milk is preferred for the preparation of rabree.

Khurchan is made in the same manner as rabree. The milk is heated over a slow fire and the thin layers of skin forming on the surface are periodically removed to the cooler parts of the vessel. When sufficiently dry, they are taken out of the vessel and cooled. The product is sometimes sweetened.

Khoa is prepared by the rapid evaporation of water from milk. It is usually prepared from buffalo milk by heating with brisk stirring in flat-bottomed shallow iron pans until the volume is reduced to about one-fifth. A scraper with a flattened end is employed to scrape off the deposit on the sides to prevent over heating and browning. When the mass assumes the consistency of dough, the vessel is removed from the fire and the contents worked with the scraper. The product is gathered in a compact mass, cooled, and packed in 2-3 lb. lots in dry leaves for the market. Alum is sometimes added to the milk during the boiling to give a smooth texture to the product.

Khoa is white in colour and smooth to the palate. A preparation with a rubber-like feel in the mouth is obtained if sour milk is used instead of fresh milk. Contamination with iron from the vessel invariably occurs. *Khoa* is consumed directly or used as an ingredient of sweetmeats. It can be kept for 3 to 4 days without deterioration. The common adulterants of *khoa* are cereal flours. Table 47 gives the average composition of *khoa*.

Khoa is made all over the country. The chief producing centres are Allahabad, Lucknow, Kanpur, Bareilly, Agra, Mathura, Saharanpur and Banaras in Uttar Pradesh; Patna and Gaya in Bihar; and Ambala, Ferozepur and Rohtak in Punjab.

CHEESE

Cheese is the product made from the curd obtained from whole or skimmed milk, with or without added cream, by coagulating the casein and further treatment of the separated curd by ripening ferments, special molds, or seasoning (Lampert, 195).

Cheese is not a popular item of food in India mainly because animal rennet is used in its preparation. Preparations, such as *Surti Paneer*, *Bandal*, and *Dacca cheese*, which are popular in certain localities, are allied to cheese. During World War II, Cheddar cheese was being produced at Anand and Nadiad for the use of the Armed Forces.

Surti Paneer is a soft variety of cheese made from buffalo milk using rennet (from the stomach of the goat) as coagulant. The chief centres of manufacture are Surat, Bombay and Dhond. Milk is warmed to about 95°F. and mixed with a starter (0.7-0.8% lactic acid) in the proportion of 0.5 oz. per 100 lb. of milk. Rennet solution is added and the coagulum formed is sliced into thin layers with a flat spoon and transferred to wicker baskets (made from bamboo splints). Salt is sprinkled between layers of the coagulum (c. 4.75 lb. salt per 100 lb. of green cheese). The whey is drained off and the coagulum turned over at intervals to facilitate drainage. The cheese is transferred to earthen pots and ripened for 12 to 36 hours. The approximate composition of *Surti Paneer* is as follows: moisture, 68; fat, 21; protein, 9; and ash, 2%.

Bandal is a soft cheese, similar to *Surti Paneer*, made from cow milk without the use of rennet. Milk is heated to boil, cooled and curdled by adding dahi. The whey is drained off and the curd mixed with salt and made into small balls. It is consumed as such or after smoking.

Soft cheese, known as *Paneer*, is made in Punjab by using berries of *Withania coagulans* as the source of a coagulating enzyme for clotting milk. Buffalo or sheep milk is warmed to about 100°F. and crushed berries of the plant are tied in a cloth and dipped in it. The milk curdles in 30-40 minutes. The coagulum is placed on a muslin cloth and the whey drained out. It is salted before consumption.

Cheese is an important dairy product in several countries. There are about 20 distinct varieties

TABLE 47—COMPOSITION OF KHOA

| | Moisture | Fat | Lactose | Proteins | Ash | Iron (p.p.m.) |
|-----------------------|----------|-----|---------|----------|-----|------------------|
| Cow milk (4% fat) | 31 | 30 | 36 | 28 | 5 | 132 |
| Cow milk (5% fat) | 25 | 34 | 32 | 30 | 4 | 161 |
| Buffalo milk (6% fat) | 29 | 32 | 34 | 24 | 4 | 140 |
| Buffalo milk (7% fat) | 28 | 41 | 31 | 24 | 4 | 127 |
| Buffalo milk (8% fat) | 23 | 44 | 30 | 22 | 4 | 151 |

TABLE 48—CLASSIFICATION OF CHEESE*

| Consistency | Unripened | Ripened by molds | Ripened by bacteria |
|-------------|------------|------------------|------------------------------------|
| Soft | Cottage | Camembert | Limburger |
| Semi Hard | Neuschatel | Brei | Brick |
| Hard | | Gorgonzola | Munster |
| | | Roquefort | Swiss & Parmesan (with gas holes) |
| | | Stilton | Cheddar & Edam (without gas holes) |

* Lampert, 198

of cheese. Table 48 gives the classification of commercial cheeses.

The processes of cheese manufacture vary in details but not to such an extent as may be suggested by the widely different characters of the final products. The best known variety is Cheddar Cheese of hard texture, popular in U.K., U.S.A., and Canada. It is prepared as follows: milk is heated to c. 85°F. and mixed with a starter. When the acidity reaches 0.18–0.2%, the milk is coagulated by adding rennet (c. 3 oz. per 1,000 lb. of milk at 30°). A small quantity (1–2 oz. per 1,000 lb.) of cheese colour is also added and the resulting curd is cut into small cubes to facilitate the draining of whey. The cubes are raked while the temperature is raised to 100°F. till the cubes attain firm consistency. The acid content of the product at this stage is c. 1%. The whey is drained off and the cubes cheddared or matted together along the sides of the vat. The curd is cut into strips, milled and stirred with salt. The salt solution thus formed dissolves a part of the protein and assists in the matting of the curd; it also controls bacterial activity and ripening rate. The salted curd is pressed in moulds to remove excess of water and ripened or cured at 40–60°F. for 3 months to 1 year or longer. The moulded product is dipped in molten paraffin to give an impervious coating and so prevent drying and mould growth.

Process Cheese is a blend of cheeses of varying degrees of ripeness and moisture content. The material is ground in a mortar after adding common salt (c. ½%) and an emulsifying agent (up to 3%) such as sodium citrate, ammonium citrate, disodium hydrogen phosphate, or Rochelle salt. The mixture is heated to about 150°F. and stirred until a plastic mass of the desired consistency is obtained. The hot product is packed in air-tight containers lined with metal foil or moisture-proof paper.

CHANNA

Channa is largely used in Bengal for making sweets. Hot cow milk is coagulated with lactic or citric acid, soured whey or lime juice under vigorous stirring. As the coagulation of milk is

carried out at the boiling temperature, the quantity of acid required is about half to one-third of the theoretical amount required to bring the pH of the milk to the iso-electric point of casein. The coagulum or channa is separated by filtration through cloth with or without pressure. The product from which whey is expelled under pressure has a stiff consistency and is used for fried preparations; the coagulum obtained without applying external pressure to expel the whey is soft in consistency; it is used for the preparation of Bengal sweets.

Channa production is concentrated in areas around Calcutta. About 1,960,000 md. of milk are used annually in making channa. The approximate composition of channa is as follows: moisture, 35–50; fat, 25–30; protein, 15–20; lactose, 2.0–2.5; and ash, 0.3–0.4%. A minimum of 10% milk fat has been prescribed as the standard for channa in West Bengal.

CASEIN

Casein is prepared from skimmed milk by coagulation with acid or rennet or by self-souring. Industrial casein is prepared in Aligarh, Anand, and Khurja. Skimmed milk, obtained as a by-product after separating cream, is allowed to sour and the curd separated by adding hot water. It is repeatedly washed with water, placed in jute bags and the whey pressed out. The green curd is broken up and dried in the sun.

Commercial casein is a yellowish powder with little or no odour. It is slightly soluble in water (0.17 g. per litre at 25°) and readily soluble in alkaline solvents. The solvents commonly employed in industry are solutions of borax, lime, ammonia, soda ash, and caustic soda. The approximate composition of lactic casein is as follows: moisture, 9–10; fat, 0.4–2.0; ash, 4–5; and nitrogen, 14–15%.

Casein or its sodium salt is used in the preparation of a variety of infant and invalid foods, such as Sanatogen. It forms the basic ingredient of a number of industrial adhesives. Casein plastics are extensively employed in the manufacture of combs, buttons, buckles, brushes, cigarette holders, and umbrella handles. Casein finds use in the

manufacture of paints and distempers, cosmetics, soaps, leather dressings, putties, and in roller and water-proofing compositions. It is an ingredient of insecticidal preparations used in horticulture and agriculture. Ferric caseinate is a tonic and blood purifier, and the bismuth salt is used as an antiseptic dressing. LANITAL, a substitute for wool, is manufactured in Italy from casein. Rennet casein is almost exclusively used for the manufacture of casein plastics and lactic casein, for adhesives, glues, distempers, patent foods, and other preparations (*Chem. Age, Lond.*, 1946, 55, 383).

The production of casein in India, during the period of World War II, was about 1,000 tons per year. The price of casein was Rs. 300 per ton in 1939 and Rs. 4,000 per ton in 1943. Casein production has dwindled in recent years.

ICE-CREAM

The term Ice-cream is applied to a variety of frozen and flavoured products containing milk as the main ingredient. Ice-cream is a high calorie food, 1 quart giving c. 1,100 calories. It cannot be used as the sole item of food as it is deficient in proteins, mineral salts, and vitamins. It is easily digested. The flavour is satisfying and it stimulates the flow of digestive juices. Being a chilled product, it is particularly liked by persons suffering from irritation of the mouth and the throat (Lampert, 229).

The essential ingredients of ice-cream are milk, cream, sugar, flavour ingredients, and edible colouring materials; condensed milk and dry milk powder are usually added to increase the concentration of solids-not-fat. Cream not only imparts a rich flavour and texture, but also facilitates the overrun, i.e., increase in volume due to entrapped air. Sugar imparts sweetness and lowers the freezing point. Stabilizers, such as gelatine, egg yolk, sodium alginate, gum tragacanth, karaya gum, starch, and sodium carboxymethylcellulose are added (c. 0.5%) to improve the body, texture and overrun, prevent the formation of large crystals of ice, improve resistance to rapid melting, and prevent shrinkage (Lampert, 224).

The process employed for the manufacture of ice-cream is briefly as follows: The ingredients are mixed and pasteurized for 30 min. at 160–65°F., homogenized at 40°F., and aged for at least 4 hr. before freezing. This treatment facilitates the entrapping of air and increases the viscosity of the mix. The mix is then frozen either in batch freezers or continuous freezers. Batch freezers consist of double-walled cylindrical vessels, the refrigerant (brine or ammonia) being circulated between the walls. The mixture is frozen to a semi-solid mass and air incorporated by stirring with rapidly revolving dasher blades. The in-

crease in volume (overrun) during the treatment is 70–100%. In the continuous process, the mixture passes through a feeding chamber in which it is rapidly frozen into a semi-solid condition and run into small packages or cans which are hardened in rooms maintained at –10 to –20°F. About 15 lb. of milk yield 1 gal. of ice-cream. Dry ice-cream powder is manufactured in U.S.A. A representative sample of the powder contained: sugar, 44; milk solids-not-fat, 25; fat, 28; stabilizer, 1; and moisture, 2%. One part of the powder is mixed with 2 parts of water and frozen in the usual manner (Lampert, 229).

Ice-cream from standard recipes are produced on a large scale in Calcutta, Bombay, Madras and other large cities. Messrs. *Magnolia Ice Cream Mfg. Co.*, Calcutta, are reported to produce 19,000 gallons of ice-cream per month in the peak season.

Indigenous ice cream preparations, e.g. *Kulfi* and *Malai-ki-Baraf*, are made and sold in many towns and cities in India.

Kulfi is a nut ice-cream frozen in small containers of conical shape. Sweetened milk, containing 20–25% added sugar, is concentrated to about half its volume. Malai, crushed almonds, pistachio, and flavouring materials, such as vanilla and essence of rose, are added after cooling. The mixture is filled into containers of galvanized iron or aluminium, closed with metal discs, and sealed with wheat dough. The containers are introduced into a freezing mixture of ice and salt till the contents freeze.

Malai-ki-baraf is frozen sweetened milk and malai. It may be mixed with fruits, coloured, and flavoured before freezing. Special devices are used for freezing the mix. A cast iron retort connected to a specially designed condenser is sometimes employed. A cylindrical space in the condenser accommodates the vessel containing the mix. Ammonium salts are placed in the retort and heated to liberate ammonia which passes through the condenser kept immersed in a tub of cold water. The condenser is then taken out of the tub and the vessel containing the mixture to be frozen is placed in the annular space with its body covered by a wet cloth or gunny. The retort is then immersed in cold water. The ammonia gas dissolved in the condenser water distills over and collects in the retort. The positions of the retort and condenser are again reversed. The differential distillation results in a progressive lowering of the temperature and the freezing of the contents of the vessel is completed in about 3 hours.

DRIED MILK PRODUCTS

A variety of dried milk products are prepared by the total removal of water from whole milk, skimmed milk, butter-milk, and whey. Malted milk is prepared from whole milk and barley malt.

TABLE 49—PRODUCTION OF DRIED MILK PRODUCTS BY NATIONAL NUTRIENTS LTD.

| | Qty (tons) |
|------|---------------|
| 1939 | 3.81 |
| 1940 | 7.15 |
| 1941 | 2.91 |
| 1942 | 4.06 |
| 1943 | 11.80 |
| 1944 | 91.57 |
| 1945 | 1,533.42 |
| 1946 | 138.60 |
| 1947 | 53.21 |
| 1948 | 19.26 |
| 1949 | 7.00 |

Milk powder is generally prepared by spray drying, while other products are made by roller drying. Roller dried products are not as easily dispersed in water as spray dried products but are equally nutritious.

Malted milk is used widely as an infant and invalid food. Malted barley is mashed along with wheat flour in warm water until the starch is converted to maltose and dextrin. The filtered extract is mixed with whole milk, small quantities of common salt and sodium bicarbonate are added, and the mixture concentrated in vacuum; the concentrate is dried in a drum or spray drier (Lampert, 172).

Dried milk products are manufactured by the National Nutrients, Ltd., Calcutta and Banaras. Whole and skimmed milk powders, Sanavita (a beverage), and Vita Milk (an infant food) are the products manufactured by this firm. Table 49 gives the production of dried milk products during the period 1939-49.

The total annual capacity of the factory, on a single shift basis, is estimated to be 100 tons (Indian Tariff Bd, Rep. Milk Powder Industry, 1951, 8).

BY-PRODUCTS

The three important by-products of the dairy industry are skimmed milk, butter-milk, and whey. Skimmed milk contains: water, 90.40; protein, 3.68; fat, 0.12; lactose, 5.00; and ash, 0.80%.

With the exception of fat and fat-soluble vitamins, it contains all the nutritive elements of milk and can serve as a wholesome food if these deficiencies are made up. Skimmed milk is used as animal feed and in the manufacture of casein, condensed milk, skimmed milk powder, cottage cheese, ice-cream, lactose, milk foods, and confectionery (Lampert, 142).

Butter-milk obtained as a by-product in the manufacture of butter from sweet cream has nearly the same composition as skimmed milk. That obtained after the separation of butter from sour cream contains lactic acid. Butter-milk is used as a beverage. Dried butter-milk is used as animal feed and in bakery products.

Whey contains the greater part of albumin, lactose, and mineral matter present in the milk, and is rich in riboflavin. Whey may be condensed or dried for use as animal and poultry feed; dried whey may also be used as an ingredient of cheese spreads and canned soups. Certain varieties of cheese are made from whey.

A method for the production of ethyl alcohol from whey has been developed in U.S.A. Whey is heated to boiling and the pH adjusted to 5. The proteins which separate out are removed by filtration. The clear whey (120 gal.) is inoculated with *Torula cremoris* (1 lb.) and fermented for 48-72 hr., at 33-40°. The yeast is separated and the alcohol distilled off from the fermented wash. The production of alcohol from whey in U.S.A., in 1947, was 262,000 proof gal. (Browne, Amer. chem. Soc., News Ed., 1941, 19, 1271; Rogosa et al., J. Dairy Sci., 1947, 30, 263; Industr. Engng Chem., 1948, 40, 990).

Lactose or milk sugar is produced in a number of countries from whey. The process employed is as follows: Whey is heated to the boiling point and lime added to precipitate albumin and mineral matter. The filtrate is concentrated to 80% total solids and cooled under constant stirring when lactose crystallizes out. The product so obtained is α -lactose ($[\alpha]_D^{20}$, +90°; solubility in water at 77 F., 17.8%). β -lactose ($[\alpha]_D^{20}$, +33°) is more soluble and is obtained by controlling the drying temperature. The specific optical rotation of an

TABLE 50—PRODUCTION OF DAIRY PRODUCTS IN MILITARY DAIRY FARMS* (Qty in tons)

| | Milk | Fresh butter | Cream | Cheese† | Tinned butter | Evaporated milk |
|------------------|--------|--------------|-------|---------|---------------|-----------------|
| 1938-39 | 9,375 | 413 | 91 | 0.04 | .. | .. |
| 1939-40 | 9,664 | 422 | 86 | 0.60 | 3 | .. |
| 1940-41 | 12,857 | 472 | 106 | 6.90 | 50 | .. |
| 1941-42 | 20,353 | 563 | 127 | 27.90 | 334 | .. |
| 1942-43 | 28,790 | 1,157 | 187 | 106.00 | 699 | 334 |
| 1943-44 | 47,392 | 1,511 | 205 | 112.00 | 1,240 | 448 |
| 1944-45 | 65,960 | 1,919 | 252 | 101.00 | 1,048 | 609 |
| 1945 (Apr.-Aug.) | 30,247 | 1,097 | 118 | 39.00 | 508 | 466 |

* Statistics relating to India's War Effort, Minist. Commerce, Govt. India, 1947, 20

† Cream Cheese and Cheddar Cheese

DAIRY INDUSTRY

TABLE 51—IMPORTS OF DAIRY PRODUCTS INTO INDIA

| | Butter (including canned) | Cheese (including canned) | Milk foods | Ghee | Condensed milk, whole, (including milk cream) | Condensed milk, skimmed | Milk powder, whole | Milk powder, skimmed | Total |
|--------------------|---------------------------------|---------------------------------|---------------|-------|--|-------------------------------|--------------------------|----------------------------|---------|
| (Qty in cwt.) | | | | | | | | | |
| 1934/35- | | | | | | | | | |
| 1938/39 (av.) | 7,611 | 10,741 | 9,328 | 290 | 24,566* | 23,887* | 4,963* | 8,652* | 90,038 |
| 1939/40- | | | | | | | | | |
| 1943/44 (av.) | 5,524 | 6,953 | 6,749 | 265 | 17,369 | 7,294 | 6,836 | 17,652 | 68,642 |
| 1944-45 | 38 | 4,652 | 11,797 | 14 | 34,887 | 282 | 17,376 | 44,287 | 113,333 |
| 1945-46 | 139 | 8,709 | 17,569 | 181 | 19,241 | 4,114 | 11,430 | 25,602 | 86,985 |
| 1946-47 | 1,655 | 7,577 | 20,569 | 5 | 92,187 | 410 | 47,134 | 50,154 | 219,691 |
| 1947-48 | 11,635 | 11,020 | 43,566 | 2 | 104,871 | 9,194 | 84,556 | 76,950 | 341,794 |
| 1948-49 | 5,041 | 4,759 | 39,362 | .. | 231,575 | 19,361 | 31,607 | 63,555 | 395,260 |
| 1949-50 | 12,769 | 12,248 | 38,511 | 111 | 131,711 | .. | 48,073 | 123,381 | 366,804 |
| 1950-51 | 11,458 | 6,207 | 53,624 | 70 | 174,333 | 12,319 | 33,811 | 130,407 | 422,229 |
| 1951-52 | 17,223 | 9,766 | 78,212 | 30 | 155,508 | 18,537 | 21,086 | 233,974 | 534,336 |
| 1952-53 | 6,910 | 5,337 | 48,087 | 42 | 37,713 | 9,545 | 8,386 | 183,679 | 304,099 |
| (Val. in lakh Rs.) | | | | | | | | | |
| 1934/35- | | | | | | | | | |
| 1938/39 (av.) | 7.47 | 7.78 | 16.21 | 0.14 | 10.15* | 4.84* | 2.78* | 2.28* | 51.65 |
| 1939/40- | | | | | | | | | |
| 1943/44 (av.) | 6.51 | 6.25 | 14.27 | 0.12 | 8.52 | 1.96 | 4.20 | 6.24 | 48.07 |
| 1944-45 | 0.09 | 4.28 | 25.34 | 0.02 | 21.43 | 0.06 | 14.95 | 13.24 | 79.42 |
| 1945-46 | 0.23 | 7.95 | 34.74 | 0.26 | 12.24 | 2.82 | 6.41 | 16.99 | 81.64 |
| 1946-47 | 3.31 | 8.47 | 44.57 | 0.007 | 59.07 | 0.26 | 65.35 | 26.14 | 207.18 |
| 1947-48 | 23.89 | 15.11 | 90.73 | 0.002 | 80.37 | 6.71 | 79.39 | 36.43 | 332.68 |
| 1948-49 | 13.54 | 8.47 | 71.29 | 0.002 | 175.68 | 14.44 | 43.53 | 48.05 | 375.00 |
| 1949-50 | 35.04 | 19.28 | 76.85 | 0.416 | 106.95 | .. | 63.65 | 81.28 | 383.47 |
| 1950-51 | 33.38 | 15.65 | 102.93 | 0.221 | 151.23 | 9.38 | 64.67 | 85.97 | 463.43 |
| 1951-52 | 53.54 | 21.18 | 159.46 | 0.080 | 157.87 | 21.35 | 33.85 | 137.50 | 624.63 |
| 1952-53 | 20.16 | 11.97 | 109.13 | 0.128 | 52.70 | 7.26 | 18.12 | 202.66 | 422.13 |

* Import in 1938-39 only

TABLE 52—EXPORTS OF DAIRY PRODUCTS

| | Butter | | Cheese | | Ghee | | Casein | | Total | |
|---------------|---------------|--------------------|---------------|--------------------|---------------|--------------------|---------------|--------------------|---------------|--------------------|
| | Qty (cwt.) | Val. (lakh Rs.) | Qty (cwt.) | Val. (lakh Rs.) | Qty (cwt.) | Val. (lakh Rs.) | Qty (cwt.) | Val. (lakh Rs.) | Qty (cwt.) | Val. (lakh Rs.) |
| 1934/35- | | | | | | | | | | |
| 1938/39 (av.) | 3,732 | 3.52 | 32 | 0.02 | 33,246 | 20.46 | 8,998 | 1.93 | 46,008 | 25.93 |
| 1939/40- | | | | | | | | | | |
| 1943/44 (av.) | 4,726 | 5.13 | 20 | 0.01 | 28,677 | 20.15 | 3,494 | 0.88 | 36,917 | 26.17 |
| 1944-45 | 38 | 0.10 | 15 | 0.02 | 224 | 0.55 | 200 | 0.19 | 477 | 0.86 |
| 1945-46 | 83 | 0.22 | .. | .. | 1,011 | 0.99 | .. | .. | 1,094 | 1.21 |
| 1946-47 | 44 | 0.11 | .. | .. | 6 | 0.01 | 3,697 | 2.33 | 3,747 | 2.45 |
| 1947-48 | 17 | 0.05 | 2 | 0.003 | 857 | 0.80 | .. | .. | 876 | 0.85 |
| 1948-49 | .. | .. | .. | .. | 4 | 0.015 | .. | .. | 4 | 0.015 |
| 1949-50 | .. | .. | .. | .. | 138 | 0.36 | .. | .. | 138 | 0.36 |
| 1950-51 | .. | .. | .. | .. | 56 | 0.073 | 39 | 0.009 | 95 | 0.08 |
| 1951-52 | .. | .. | 13 | 0.03 | .. | .. | .. | .. | 13 | 0.03 |
| 1952-53 | .. | .. | .. | .. | 11 | 0.046 | .. | .. | 11 | 0.05 |

equilibrium mixture of α - and β -forms is +55.3". Milk sugar is an ingredient of many infant foods. It is added to diluted cow's milk for infant feeding. It is used as a base for pills and tablets, fondants and candies. It is a constituent of the culture medium employed in penicillin production. It is an ingredient of mixtures used for smoke screens. It is a good nutrient for acid forming bacteria and is, therefore, used in acidophilus milk therapy. Unlike other sugars, lactose has no fattening effect on grown animals.

Messrs. Bengal Chemical and Pharmaceutical Works, Calcutta and Messrs. Gita Press, Gorakhpur, are the principal producers of lactose in India. The Panel on Fine Chemicals, Drugs, and Pharma-

ceuticals has estimated the requirements of lactose at 1.5 million lb., recoverable from 30 million lb. of whey, for the production of 1 million units of penicillin per year (*Rep. Panel on Fine Chemicals, Drugs & Pharmaceuticals, Govt. India, 1947, 70*).

PRODUCTION AND TRADE

Statistical data on the production of dairy products in India are not available. Available data from military dairy farms, for the period 1938/39-1945/46, are summarized in Table 50.

Tables 51 and 52 give the imports and exports of dairy products into and from India. Small quantities of dairy products are imported by land from Pakistan, Afghanistan, and Burma.

DEHYDRATION

The keeping quality of food materials is greatly influenced by their water contents. Fruits, leafy vegetables, meat, fish, and dairy products containing high percentages of water deteriorate more rapidly than root crops and cereals which are comparatively dry. Drying by exposure to the sun is the method adopted in several countries for prolonging the storage life of fruits and fish. In India, more food is preserved by sun-drying than by any other means. Vegetables like tapioca, chillies, peas, turmeric, and ginger; fruits like figs, amla (*Phyllanthus officinalis*), mango, banana, and coconut; and fish are preserved by sun-drying. The use of machinery for drying and the development of the dehydration industry are comparatively recent and, like canning, dehydration is assuming increasing importance as a process of food preservation.

Tapioca—Sun-dried tapioca chips are used as staple food in Travancore-Cochin. They may be converted into semolina or flour by grinding and sieving (Mudaliar, *Madras agric. J.*, 1951, **38**, 12).

Figs—Dried figs are produced in Poona on a commercial scale by sun-drying. The dried product is reported to be comparable in quality to that imported from Persia, Afghanistan, Greece, and Smyrna (*Bull. Dep. Agric. Bombay*, 1926, No. 133, 12).

Banana—In Thar district of Bombay State, whole fingers of *Rajeli* variety of bananas are dried in the sun on bamboo platforms.

Banana flour is produced on a small scale in Madras, Mysore, and Travancore-Cochin. It is prepared from fully matured but slightly unripe bananas. The fruits are dipped in boiling water for 2-3 minutes and the peels removed by hand. The pulp is cut lengthwise into halves or quarters, spread in a single layer on slat bottom bamboo trays, stacked in a "home drier" or in a specially constructed room, and dried at a temperature of c. 145°F. Dried slices are powdered and sifted. A more attractive product, which is white in colour, is obtained by exposing the slices to fumes of burning sulphur for 20 minutes before drying. Banana flour is prepared from *virupakshi*, *bontha green*, and *bontha ashy* varieties of banana in south India. It is a rich source of vitamins of the B complex, vitamin C, and available iron; it is palatable and is highly valued as a food for persons with weak digestion (Naik, 308).

"Plantain figs" are prepared from mature but hard bananas. The fruits are peeled after dipping them in boiling water for 2-3 minutes and cut lengthwise first into halves and then into 3 or 4 pieces. The slices are dried in the sun for about a week in fly- and damp-proof trays. Dehydration may also be effected in home driers or

specially constructed drying rooms. *Bontha ashy*, *bontha green*, and *virupakshi* varieties of banana are used for making plantain figs (*Agric. Marketing India, Rep. Marketing Bananas, Marketing Ser. No. 49*, 1945, 30; Naik, 308).

Mango—Dried juice of ripe mango fruits is sold under the name of *Amavat* or *Am ka papar*. Partial dehydration of juice and pulp is carried out in households and on a cottage industry basis in many localities by spreading the material on shallow pans and exposing to the sun. The pulp may be mixed with sugar and warmed before drying. The dried product is brown in colour and used in ice creams, puddings, cakes, and other edible preparations. Investigations carried out at the Industrial Research Laboratory, Bombay, have shown that a crisp product with good keeping quality is obtained by drying the fresh juice of ripe mangoes, spread out in trays to a depth of $\frac{1}{8}$ in., first at a temperature not exceeding 50° for 4-6 hr. in a shelf drier and then at 60° for 1 hr. in a vacuum drier. Addition of cane sugar (10%) improves the taste and treatment of juice with sulphur dioxide improves the colour, but affects the flavour. The product has satisfactory keeping qualities. It should be packed in air-tight containers for the market (Mandlekar *et al.*, *J. sci. industr. Res.*, 1951, **10A**, 342).

Copra—More than 50% of the coconuts produced in India is used in the production of copra. Ball copra, used exclusively for edible purposes, is obtained from mature coconuts stored with the husk intact for a period of 8-12 months in a shady place. During this period the water inside the nut evaporates and the kernel gets detached from the shell. The nut is then husked and the shell broken, when the dry kernel emerges in the shape of a ball. The bulk of ball copra is produced in Mysore; small quantities are produced in Malabar and Godavari districts of Madras State.

Cup copra is used mainly for the production of oil. Mature coconuts are harvested and dehusked with the aid of sharp-edged spikes planted firmly in the earth. The dehusked nuts are cut latitudinally into two cup-like halves and the water inside let out. The cups are arranged in close rows in the drying yard in such a manner that the white kernel is fully exposed to the sun. The cups are covered at night with tarpaulin or screens made of bamboo and coconut leaves. Wire or coir yarn netting is spread over the drying yard as a protection against birds. The kernel gets sufficiently dry to be detached from the shell in 2-3 days. Copra is further dried in the sun for 4-7 days before milling.

During rainy months copra is prepared by drying coconut kernel in a chamber kiln. The

DEHYDRATION

walls of the chamber are made of brick or mud and the roof covered with tiles or plaited coconut leaves. A platform of bamboo or wooden slats is erected, 5-6 ft. above the fireplace, and the coconut halves, and later copra cups, are spread on the platform. A slow fire is maintained underneath the platform by burning coconut shells. The kilns are often no better than smoke chambers and the copra produced is dark in colour.

In the East Godavari district, coconut shell charcoal is used as fuel for kilns. The cups are exposed to the sun during the day and transferred to kilns during the night.

Hot air driers have not come into use in India. The Indian Central Coconut Committee have recently sanctioned grants (Rs. 12,900) for the construction of a hot air kiln at Kozhikode.

Pearson's patented kiln is generally employed for drying coconut kernel in many estates in Ceylon. The kernel is diced into small chips to ensure uniform and quick drying. The drier is of the rotary-louvre type comprising a shell with a series of radial plates fitted in forming channels integral with the shell, into which hot air from a manifold at one end is led in. The drier revolves at slow speed and dried chips travel to the discharge end (Kuruvila, *Indian Cocon. J.*, 1947-48, 1, 41; 1948-49, 2, 30).

Desiccated coconut is an important commercial product produced in Ceylon. It is not manufactured in this country at present; Messrs. *Kerala Coconut Industries (Travancore) Ltd.*, propose to undertake the manufacture of the product in the near future. The process employed in the manufacture of desiccated coconut in Ceylon is as follows: Fully matured coconuts are harvested and stored for 1½ to 2 months. They are then dehusked and shelled. The brown outer rind of the kernel is pared off with a knife and the milk-white meat washed in fresh water and fed into a shredding machine — disintegrator. The shredded material is spread out uniformly in trays and dried in desiccators or in heating chambers fitted with flues and exhaust fans. Hot air from a furnace fired with coconut shells is drawn into the desiccators and the temperature maintained at c. 180°F. The dried product is automatically transferred to an adjacent chamber to cool and then graded with the help of revolving sifters. The product is packed in plywood chests lined with grease-proof paper, aluminium or tin foil. Desiccated coconut is used in the manufacture of cakes, pastries, chocolates, and a variety of Indian sweets and chewing compositions.

About 43,500 tons of edible copra are annually produced in India. The output of milling copra is about 175,000 tons. Table 1 gives the annual production of milling copra during the period 1945-1950.

TABLE 1—PRODUCTION OF MILLING COPRA IN INDIA

| | Qty (tons) |
|---------|---------------|
| 1945-46 | 175,130 |
| 1946-47 | 175,542 |
| 1947-48 | 174,035 |
| 1948-49 | 175,256 |
| 1949-50 | 183,456 |

Fish—For lack of adequate transport more than 50% of the fish produced in India is sun-dried and marketed. Sun-drying is carried out in Madras, Bengal, Bombay, Travancore-Cochin, Orissa, Assam, Saurashtra, Bihar, Mysore, and Hyderabad. Small or thin fishes, such as Bombay duck, ribbon fish, prawns, silver bellies, and white bait, are particularly suitable for sun-drying. In the coastal areas, the catch is spread on the beach in a thin layer on a coir mat, cadjan leaves or bamboo *thatties* to prevent admixture with sand, and dried for a day or two. The fish are periodically turned over during the day and heaped up in enclosures during the night. On the Gujarat coast and in Saurashtra all varieties of fish, except jew fish, are sun-dried. Sea and estuarine fishes are dried on the foreshore in Bengal. Fresh water carps, such as labeos and catla, are preserved in Assam by sun-drying. The fish are gutted and laid flat side by side on mats made of *nal* reeds and exposed to the sun.

Large fishes, such as seer, pomfrets, cat fish, jew fish, and perches, are cured by salting. In this process, the fish are split through the dorsal line, guts and gills removed, the vertebral column severed from the flesh side, and scores made on the fleshy parts by passing the knife lengthwise. The fish are then washed, salt applied to the scores and rubbed all over the surface. Large sharks are cut into pieces of convenient size and filleted. The proportion of salt used varies in different places, from 1 part of salt : 3 parts of fish to 1 part of salt : 8 parts of fish. The salted fish are arranged in layers in half-barrels, tubes, dug-out canoes, or cemented tanks. In the Northern Circars (Madras), salting is done in earthen pots and in Tamil districts, in pits, mud pots, or hollowed palmyra butts. The fish are kept in salt for 12-13 hr., taken out, washed in the brine found in the salting vessels, and dried in the sun on coir mats or cadjan leaves spread on the sand. Nearly 32 lakh maunds of sea-fish are cured in this manner in about 151 curing yards distributed on the east and west coasts of India (*Agric. Marketing India, Brochure Marketing Fish*, 1948, 15, 29).

Prawns are cured by boiling. Crustaceans are cooked in water in wide mouthed copper vessels till they become reddish brown and then

TABLE 2—PRODUCTION OF DRIED FISH IN INDIA*
(Qty in thousand maunds)

| | Total production | Sun-dried fish | Salted fish‡ |
|----------------|---------------------|-------------------|-----------------|
| Bombay | 1,442 | 453 | 335 |
| Madras | 1,854 | 1,609 | 1,405 |
| Cochin | 642 | 167 | 43 |
| Travancore | 2,664 | 410 | 1,342 |
| Orissa | 629 | 95 | 24 |
| Bengal‡ | 4,862 | 850 | 150 |
| Assam‡ | 722 | 50 | 15 |
| Bihar | 959 | 3 | (a) |
| Uttar Pradesh | 147 | (a) | (a) |
| Kathiawar | 111 | 20 | 1 |
| Madhya Pradesh | 156 | (a) | (a) |
| Punjab‡ | 33 | (a) | (a) |
| Hyderabad | 20 | 2 | (a) |
| Mysore | 10 | 2 | .. |
| Other areas | 117 | 15 | 2 |
| Total | 17,368 | 3,676 | 3,316 |

* *Brochure Marketing Fish*, 32

‡ The major part of the salted fish is produced by the dry-salting process

‡ Undivided India

(a) Negligible

dried. Dried prawns are put in jute sacks and beaten with a block of wood to separate the shells. Kernels are sorted out and dried before storage. A new process developed by the Madras Fisheries Department comprises of the following operations: Blanching by dipping in boiling water or 6% salt solution, shelling, immersing in saturated brine for c. 20 minutes, drawing off the brine, and partial drying in open sheds or in a drier. The drying is stopped when on pressing between the thumb and the finger, an impression is left on the material. The product is put into tins, sealed, and filled with carbon dioxide. Sun-dried prawns keep well for nearly a year.

Table 2 gives the quantity of dry fish produced in various States in India.

DEHYDRATION FACTORIES

Dehydration by artificially produced heat under controlled conditions of temperature, humidity, and air flow has several advantages over sun-drying. Cooked 'dehydrated' foods resemble more closely cooked fresh foods in flavour and colour than cooked 'sun-dried' products; dehydrated food products are prepared under sanitary conditions; dehydration by the use of machinery can be carried out all the year round and material loss due to rain and inclement weather is prevented. Dehydration is somewhat more expensive than sun-drying, but the yields are higher and the appearance and cooking quality of the products are better (Jacobs, I, 570).

Dehydration brings about a reduction of 75-85% in the weight of foodstuffs and saves space both

for storage and transport. It is preferred to canning on account of the saving in tin plate and packaging material. Dehydrated products, however, are less convenient to prepare for the table than canned foods.

The methods usually employed in dehydration factories are: (1) natural draft dehydration, (2) forced draft dehydration, and (3) roller or spray drying.

In the natural draft dehydration method, a drying chamber with slatted floor, placed over a heater, is employed. Hot air from the heater passes through the material spread over the floor and escapes through a vent in the roof of the chamber. The process is uneconomical in fuel consumption; it is adopted only in factories where abundant waste heat is available.

Forced draft dehydration has almost entirely replaced natural draft dehydration. Various forms of driers—batch driers, tunnel driers, conveyor driers, pneumatic driers, rotary-louvre driers, and spray driers—are in use.

The batch drier consists of a chamber containing loaded trucks carrying trays in which the material to be dried is spread. Heaters and fans are provided in the roof space and hot air is blown through a slotted wind chest at one side across the trays and out through slots leading to a chest on the opposite wall. Cabinet driers are used for dehydrating small batches of vegetables, fruits, and meat.

Tunnel driers are particularly well adapted for large scale dehydration. The material is spread in trays, loaded on trolleys, and conveyed through a tunnel through which hot dry air is circulated. A two-stage drying is the rule in modern practice. In the primary tunnel, the air flow is concurrent with the flow of the material and in the secondary tunnel, the air flow is counter-current. The primary tunnel is operated at a higher temperature than the secondary. The tunnels are arranged in pairs parallel to one another with a chamber between them. The secondaries are so situated that the trolleys from the primaries are directly pushed into them or, one member in each pair serves as the primary and the other, as the secondary. In some factories, the secondary is a continuation of the primary and is separated from it by a swing door (Morris, 37).

In the conveyor drier, the material is carried on a perforated belt which travels through the tunnel at a controllable speed. Hot air is blown over, across, or through the material.

The pneumatic drier is a recent development. The material to be dehydrated is supported and carried along the air stream, the dried product being deposited at a convenient part of the plant.

In the rotary-louvre drier, the material enters through one end of a revolving hollow drum and

DEHYDRATION

discharged at the other end by a system of spiral flanges. The heat is furnished either by hot gases passing through the space between the cylinder and the outer jacket, or by steam coils which raise the temperature of the air blown directly on the revolving material through louvres. Rotary driers are employed for drying meat and potatoes.

Spray driers are used for drying liquid foods, such as milk and egg pulp. The liquid material is sprayed into a large chamber into which hot dry air is blown. The dehydrated material collects at the bottom, away from the hot zone, and is removed. A part of the dried material is carried along with the escaping air and is recovered by a dust collector or by a coarse spray of the liquid to be dried. The liquid is sprayed into the chamber through nozzles by a jet atomizer under pressure, or by a disc atomizer in which the liquid is fed by gravity on to a revolving disc. Disc atomizers are superior to jet atomizers in certain respects; they are suitable for viscous liquids, e.g. thick *purees*, and permit a higher degree of pre-concentration with consequent fuel economy. The air flow may be concurrent or counter-current with the flow of spray. Drying is almost instantaneous and due to the cooling produced by evaporation, the particles are not subjected to excessive heat. The method is particularly well adapted for drying heat-sensitive materials.

In the roller drier, a revolving cylinder, heated from inside by steam under pressure, is so placed over a trough containing the liquid that it comes into contact with the liquid as it rotates; the film of liquid, which the rotating cylinder carries, dries up and is removed by a stationary scraper into a collector. Alternatively, an auxiliary roller dipping into the liquid spreads a film of liquid over the heated cylinder or the liquid is sprayed on the hot cylinder. In double-roller driers, the liquid is fed between two-heated cylinders, which as they revolve carry the film downwards, each acting as a spreader for the other. The drier may be enclosed in a vacuum chamber and drying effected at a low temperature. Roller drying is relatively cheap and quick; it is employed in the preparation of milk powder, soup powder, fish flakes, and potato flakes.

In the band drier, liquid foods are spread in a thin film on a band of woven wire travelling through a hot-air oven. The dried product is removed by scraping. The wire band may be enclosed in a chamber and the drier operated under vacuum.

Vacuum-ice drying or Freeze drying is a comparatively recent development. The material to be dried is frozen and the ice which separates out is sublimed under high vacuum. The material does not harden or suffer any adverse change. A large variety of food materials—citrus juices,

vegetables, milk, egg white, minced meat, fish, and coffee and tea infusions, can be dried by this process (Morris, 47).

Radio frequency heating and infra-red heating are employed as adjuncts to conventional drying processes to reduce the moisture content to below 1%.

DEHYDRATION OF VEGETABLES

Certain vegetables, e.g. spinach, sweet potato, corn peas, string beans, tomato, pumpkin, cabbage, and beet, are suitable for both canning and dehydration; a few others, e.g. potato, carrot, celery, onion, and sprouts, are seldom canned and are well adapted for dehydration. Potato ranks first among dehydrated vegetables and the demand for dehydrated potato exceeds the combined demand for all other vegetables.

Dehydration comprises a sequence of operations—pre-treatment, drying, compressing, and packaging.

Pre-treatment includes washing, peeling, trimming, stripping, shredding, and blanching.

Vegetables, selected for quality and size, are washed by water spraying or in rotary washers. The washing is repeated after peeling.

Root vegetables are peeled before drying. Potatoes, carrots, turnips, and beets are peeled by abrasion or by treatment with hot lye, hot brine, or steam at high pressure.

The equipment used for abrasion peeling consists of pairs of horizontal drums rotating in the same direction and lined with graded carborundum. Water sprayers are used for loosening the dirt and assisting peeling. Abrasion peeling is being replaced by lye peeling in many factories.

In lye peeling, the vegetables are dipped for a short period (3 min.) in boiling caustic soda (10%) whereby the skin is loosened; the skin is washed off by tumbling in a washing machine. Boiling salt solution (b.p., 220°F.) can be used in the place of lye. The process is suitable for peeling carrots, but it darkens potatoes necessitating their immersion in sulphite solution for restoring the natural colour.

Peeling may be effected by steaming, radiant heat, or by heating over gas flames and tumbling in a washer. Flame peeling and pressure steam peeling are employed on a commercial scale in U.S.A. (*Misc. Publ. U.S. Dep. Agric.*, No. 540, 1944).

Peeled root vegetables are cut into cubes, strips, flakes, or slices. Cabbage is cored, cut into shreds, and washed to remove dirt and grit. Potato strips are washed to remove free starch grains which, if allowed to remain, gelatinize during blanching and cause the strips to stick together during drying. Potatoes may be riced, i.e. cooked, mashed, and extruded into vermicelli-like threads.

Sliced vegetables are blanched or scalded by partial cooking in boiling water or live steam to inactivate the enzymes which cause off-flavours. This treatment also improves the keeping quality of the dehydrated product. Other advantages of blanching are expulsion of air from tissues and marked reduction in drying time; it ensures a soft product on reconstitution and helps the retention of carotene and ascorbic acid during storage. The disadvantages are: increased cost of production and loss in soluble solids (Jacobs, III, 1792).

Water-scalding is commonly adopted in U.K. Sliced vegetables are placed in perforated cylinders and revolved in a tank containing boiling water, or they are taken in wire baskets and held in boiling water for a definite period. Ascorbic acid (c. 52%) and other soluble nutrients are lost during the treatment. It is usual to employ the same liquid for scalding successive batches, a process which is known as Series Scalding. Carrots are blanched by series scalding (Morris, 59).

Steaming is adopted in U.S.A. and Canada. The vegetables are passed on belt conveyors or on trays through a tunnel into which live steam is injected. A small amount of sodium sulphite solution is spread on shredded cabbage prior to steaming. Water-scalded potatoes have better cooking properties than steam-scalded potatoes although the latter possess higher nutritive value and better colour. Onions are usually dried in slices without scalding.

Blanched vegetables are immediately cooled by passing the trays (made of galvanized iron or stainless steel) containing the material through coolers in which refrigerated air is circulated. The material is then dried in batch or continuous driers.

Dried vegetables are compressed into blocks and packaged. They are heated to 60–70° in a current of warm air and pressed while warm in steel moulds at 2,000–3,000 lb./sq. in. for 10–45 sec. This treatment is suitable for vegetables containing a high percentage of soluble solids, e.g. carrots, beet roots, and runner beans. In the case of leafy vegetables, like cabbage, which are rendered brittle by dehydration, conditioning in hot and humid air to make them flaccid is necessary before applying pressure.

The compressed material is packed in tin plate containers previously treated in a phosphate or chromate bath or lacquered to prevent corrosion. Cans 13½ in. high × 9¼ in. square in cross section, with a capacity of 4 gal. are economical from the point of view of space and metal. The cans are provided with lever lids of black plate covered by tagger plates of tin. The lids are forced in by mechanical pressure and soldered.

Cans are sometimes filled with nitrogen or carbon dioxide. In-package desiccants, such as dehydrated lime, are placed in separate containers and packed along with dehydrated vegetables in 4 gal. tin cans. A storage life of one year may be ensured by the use of desiccants (Minist. Fd, U.K., *Vegetable Dehydration*, Scientific and Technical Series, 1946, 174).

DEHYDRATION OF FRUITS

The pre-treatment for fruits is similar to that for vegetables. Fruits are selected for size and ripeness, washed, peeled, pitted, dipped or sulphured, and dehydrated. Washing is carried out by low pressure sprays or in rotary washers to prevent damage. Apples are peeled by knife peelers and peaches, by dilute lye. Apples are sliced or sectioned after peeling; unpeeled sections are dried for use in the preparation of jellies. Apricots and peaches are halved and pitted. Pears are halved, steamed, and the calyx removed.

Grapes, prunes, berries, and cherries are dried whole. They are dipped in an alkaline solution (sodium carbonate or lye solution, 0.5% or less) at 200–212°F. for the removal of the waxy skin. An emulsion of olive oil and sodium carbonate or lye is sometimes employed in the dipping bath. The dipped product is sulphured by exposure to sulphur dioxide or by immersion in sodium bisulphite or sulphurous acid solution. The sulphur dioxide absorbed during this treatment prevents darkening during drying, prevents spoilage, repels insects, and preserves the nutritive qualities. The quantity of sulphur dioxide absorbed should be large enough to allow for its loss during drying and subsequent storage (Jacobs, III, 1790).

Fruits are dried in cabinet driers or in tunnel driers. Conveyor driers are commonly employed in U.S.A. for drying fruits.

DEHYDRATION OF ANIMAL PRODUCTS

Animal products, such as meat, fish, eggs, and milk are dehydrated to yield products which can be stored safely without refrigeration under varying conditions of temperature and humidity. The dehydration of meat is a relatively new industry. Cutter type cattle with about 10% fat and boneless shoulders of pork with about 20% fat are suitable for drying. Meat and chicken are defatted before dehydration. The meat is first boned and fed into a rotary cutter. Pieces (1½ in. × 2 in. × 3 in.) are cut and pre-cooked in a steam-jacketed pan and minced. The minced material is cooked at 160–175°F. for 30–45 minutes under 3–5 lb. pressure with stirring and cooled. Beef re-absorbs all the liquids surrounding it. Pork does not absorb the juices; they are therefore drained off, skimmed free of fat, vacuum-concentrated to about one-fifth of the volume,

DEHYDRATION

and later mixed with the dried product. Cooked meat is passed through a meat chopper or grinder and dried in continuous rotary driers; tunnel, belt conveyor, or cabinet driers may also be used. Drying takes about 2½ hr. when the inlet air temperature is 300–315°F. and the temperature at the surface of the meat is 212°F.; the final product contains 10% moisture. Dehydrated meat is pressed at 1,500–2,000 lb./sq. in. pressure, packed and sealed in cans under 20 in. vacuum. The storage life is enhanced by adding, to the extent of about 30%, cereals, such as corn meal, rolled oats, or rice, to the ground meat prior to cooking. The addition also improves the flavour of the reconstituted product. Dehydration reduces the volume to about 16% and compression further reduces it to about 10%. Dehydrated meat is reconstituted by stirring in hot or cold water and cooking (Jacobs, III, 1806, 1815).

Fish—Cod, haddock, whiting, herring, and salmon can be dehydrated satisfactorily. Dog fish, skate, and shark are not suitable for dehydration. Fish are washed, skinned, filled, minced, cooked, re-minced, and dried. During the cooking in retorts (½ hr. at 2 lb./sq. in. pressure), 30–40% of the weight of the fish is lost through drip. Sometimes, whole fish are cooked for about 20 minutes at 12 lb./sq. in. pressure, then flaked, minced, and dried. Fish are dried in trays or on continuous belts in tunnels. The moisture content of the final product should not exceed 10%. Fish are compressed into blocks while moist and dried before packing. The dehydrated product is reconstituted by immersion in cold water.

Egg—Fresh egg pulp contains 13–14% of soluble digestible protein and about 11% fat. It is rich in vitamin A, calcium, iron, and phosphorus; it contains nearly twice as much vitamin B₁ as meat but contains no vitamin C.

Eggs, previously candled and chilled, are broken by hand against a blunt knife edge mounted above a tray carrying a large number of cups. The pulps are examined, mixed, and sieved or screen-

ed to break up the thick white and to remove shell pieces. The pulp is spray-dried at 70–105°. The dried powder is cooled rapidly and packed. The handling and drying equipments are made of aluminium or aluminium alloys. Egg powder is reconstituted by mixing with three times its weight of water and allowing to stand for about 20 minutes with occasional stirring (Morris, 87).

Milk—Milk is spray-dried to give a powder containing 2% moisture.

Table 3 gives the temperatures used for dehydration and the moisture contents of some dehydrated products.

NUTRITIVE VALUE

The nutritive value of dehydrated products is influenced by conditions of storage. Carotene and ascorbic acid are sensitive to oxidation; riboflavin is unstable when exposed to light; and thiamine is destroyed by sulphur dioxide. Ascorbic acid is well retained in dehydrated products. The destruction of vitamin B₁ in meat starts at 80° and is almost complete at 118–125°. The biological value of proteins does not suffer if meat is dehydrated at 80°. Table 4 gives the analysis of fresh, canned, and dehydrated vegetables and animal products [Mark *et al.*, *Food Ind.*, 1943, 15 (4), 59; Morris, 14].

Cooked vegetables, both fresh and dehydrated, have approximately the same nutritive value owing to the compensating effect of two sets of factors, viz. loss of solubles including sugars and vitamins, and difference between the dehydration and reconstitution ratios which tends to give a more concentrated product. Dehydrated vegetables during reconstitution take less water than was originally present in the fresh material. Table 5 shows dehydration and reconstitution ratios of some vegetables and fruits (Allen & Mapson, *J. Soc. chem. Ind., Lond.*, 1944, 63, 78; Minist. *Fd.*, U.K., *Vegetable Dehydration*, 1946, 13; Jacobs, III, 1816).

It is clear from Table 5 that in all the cases, excepting that of potato, the reconstituted product provides a more concentrated food than the fresh material. The loss of material in processing potato is not compensated during the reconstitution and there is a net loss in food value.

EXAMINATION OF DEHYDRATED FOODS

In the routine examination of dehydrated vegetables the following values are determined: (1) moisture content, (2) peroxidase activity, and (3) sulphur dioxide content. The peroxidase actively gives an indication of the adequacy or otherwise of blanching or scalding; peroxidase is present if the sample on wetting with guaiacol reagent (mixture of equal volumes of 1% guaiacol solution in distilled water and '5 volumes' hydrogen peroxide) turns red-brown in less than one

TABLE 3—DRYING CONDITIONS AND MOISTURE CONTENTS*

| | Drying time hr. | Drying tempera- ture °F. | | Moisture content of dried product % |
|-----------------|-----------------------|-----------------------------------|--------------|---|
| | | initial °F. | final °F. | |
| Potato (strips) | 5–8 | 190 | 140 | 7 |
| do. (riced) | 1–1½ | 190 | 140 | 5 |
| Cabbage | 4–5 | 190 | 140 | 5 |
| Carrot | 5–8 | 190 | 140 | 5 |
| Meat | 4–5 | 185 | 158 | 7.5 |
| Fish | 4–5 | 185 | 158 | 7.5 |
| Egg† | .. | 250–300 | 120–150 | 5 |
| Milk | .. | 260 | 160 | 2–3 |

* Morris, Appendix facing p. 172

† Spray-dried produ t

TABLE 4—ANALYSIS OF FRESH, CANNED, AND DEHYDRATED VEGETABLES AND ANIMAL PRODUCTS

| | Protein g./100 g. | Calcium mg/100 g. | Iron mg/100 g. | Vitamin A i.u./100 g. | Pro-vitamin A i.u./100 g. | Vitamin B ₁ i.u./100 g. | Vitamin C mg/100 g. |
|--|----------------------|----------------------|-------------------|--------------------------|------------------------------|---------------------------------------|------------------------|
| Carrot, fresh | 1.1 | 47 | 0.6 | 0 | 20,000 | 20 | 4 |
| Carrot, canned | 0.9 | 50 | 0.5 | 0 | 20,000 | 10 | 3 |
| Carrot, dehydrated | 8.0 | 560 | 5.0 | 0 | 150,000 | 100 | 20 |
| Potato, fresh | 2.0 | 15 | 0.8 | 0 | 0 | 40 | 35-5 |
| Potato, canned | 2.0 | 25 | 0.6 | 0 | 0 | 30 | 22 |
| Potato, dehydrated | 9.7 | 82 | 3.2 | 0 | 0 | 0 | 30-5 |
| Cabbage, fresh | 2.1 | 55 | 0.8 | 0 | 90 | 25 | 65 |
| Cabbage, canned | 2.1 | 55 | 0.8 | 0 | 90 | 25 | 40 |
| Cabbage, dehydrated | 21.0 | 550 | 8.0 | 0 | 900 | 0 | 300-150 |
| Beef, boneless, fresh | 14.0 | 4 | 3.8 | 50 | 0 | 28 | 0 |
| Beef, boneless, canned | 26.0 | 13 | 9.8 | 50 | 0 | 0 | 0 |
| Meat, minced & dehydrated (30% fat) | 59.0 | 15 | 11.5 | 150 | 0 | 84 | 0 |
| Meat, minced & dehydrated (45% fat) | 45.0 | 15 | 11.5 | 150 | 0 | 84 | 0 |
| Egg, whole, fresh | 13.4 | 60 | 3.0 | 400 | 0 | 50 | 0 |
| Egg, whole, canned | 13.4 | 60 | 3.0 | 400 | 0 | 50 | 0 |
| Egg, whole, spray-dried | 46.8 | 210 | 11.0 | 1,400 | 0 | 100-200 | 0 |
| Fish (white), fillets, fresh | 17.0 | 25 | 1.0 | 0 | 0 | 20 | 0 |
| Fish (white), fillets, dehydrated | 30.0 | 114 | 4.0 | 0 | 0 | 90 | 0 |
| Salmon, canned | 19.7 | .. | .. | 100 | 0 | 10 | 0 |
| Whole milk, liquid, fresh | 3.3 | 120 | 0.1 | 70- 200 | 0 | 12 | 2.5 |
| Whole milk, liquid, spray-dried | 25.6 | 890 | 0.8 | 550-1,600 | 0 | 85 | 0-16 |
| Whole milk, liquid, roller-dried | 25.6 | 890 | 0.8 | 550-1,600 | 0 | 80 | 0-13 |

TABLE 5—DEHYDRATION AND RECONSTITUTION RATIOS OF DEHYDRATED VEGETABLES AND FRUITS

| | Dehydration ratio | Reconstitution ratio |
|---------------|----------------------|-------------------------|
| Apple | 10 : 1 | 8 : 1 |
| Cabbage | 18.5-14 : 1 | 7-8 : 1 |
| Carrot | 10 : 1 | 6-7 : 1 |
| Potato | 4-5 : 1 | 4-5 : 1 |
| Potato, sweet | 4 : 1 | 3 : 1 |
| Onion | 10 : 1 | 6 : 1 |

TABLE 6—PRODUCTION OF DEHYDRATED PRODUCTS IN INDIA (1944-46)*

| | Qty (tons) |
|--------|---------------|
| Potato | 1,480 |
| Onion | 1,662 |
| Meat | 1,944 |

*Information from Ministry of Food

minute (Minist. Fd, U.K., *Vegetable Dehydration*, 110).

Routine tests for dehydrated meat and fish include: (1) water content, (2) culinary test, (3) particle size, (4) re-absorption of water, (5) fat content, (6) water soluble constituents, (7) peroxide value of fat, and (8) free fatty acids and mineral salts.

Eggs are tested for (1) flavour, (2) water content, (3) aerating power, (4) creaming, and

(5) pH and free fatty acids; vitamin contents are determined periodically.

THE INDIAN INDUSTRY

Dehydration of foods on a factory scale was undertaken in India during World War II to meet the requirements of the Armed Forces. The production of dehydrated potatoes was started in 1942, and of onions and other vegetables, a little later; dehydration of meat was started in March 1943. The demand for dehydrated vegetables and meat ceased soon after the war, and as there was no civilian demand, the factories were closed down by the end of 1946. Altogether 23 factories—16 for dehydration of vegetables and 7 for dehydration of meat—were working in the Indian Dominion during the war. Table 6 gives the production of dehydrated products during the period 1944-46.

Trade. Table 7 summarizes the data on imports of dried, salted, and preserved fruits into India. Table 8 gives the inter-State rail and river-borne trade of dried fruits in India.

Iran is the principal source of supply of currants and raisins, and Iraq, of dates. A small quantity of dates is supplied by Iran, Bahrein Islands, and Maskat territory. Other dry fruits are obtained from Portuguese East Africa, Burma, and Ceylon.

Table 9 summarizes the data on imports and exports of dry fish into and from India. Maskat Territory, Turkey, Iran, and Japan are the main exporters of unsalted fish. Salted fish is

DEHYDRATION

TABLE 7—IMPORTS OF FRUITS—DRIED, SALTED, OR PRESERVED

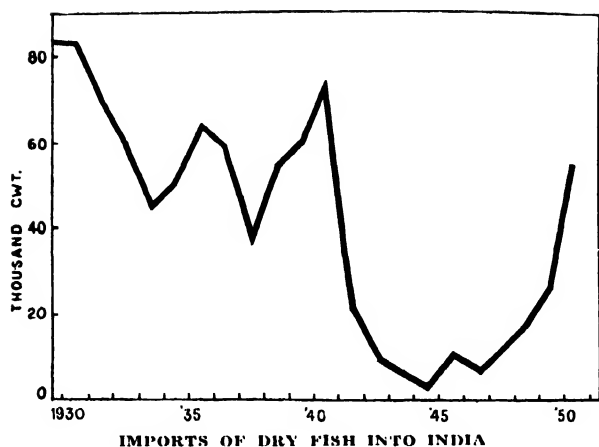
| | Currants and raisins | | Dates | | Other sorts | |
|-----------------------|----------------------|--------------------|---------------|--------------------|---------------|--------------------|
| | Qty (tons) | Val. (lakh Rs.) | Qty (tons) | Val. (lakh Rs.) | Qty (tons) | Val. (lakh Rs.) |
| 1934/35-1938/39 (av.) | 836 | 1.68 | 65,980 | 52.24 | 11,495 | 19.98 |
| 1939/40-1943/44 (av.) | 496 | 1.42 | 43,353 | 52.07 | 597 | 3.01 |
| 1944-45 | 40 | 0.23 | 30,936 | 128.75 | 149 | 0.91 |
| 1945-46 | 11 | 0.09 | 33,738 | 153.38 | 191 | 1.24 |
| 1946-47 | 125 | 1.40 | 66,354 | 226.98 | 3,552 | 24.65 |
| 1947-48 | 373 | 3.38 | 60,230 | 212.34 | 2,250 | 16.07 |
| 1948-49 | 5,092 | 47.16 | 39,536 | 153.14 | 2,619 | 36.41 |
| 1949-50 | 3,718 | 41.49 | 52,191 | 268.97 | 1,850 | 25.04 |
| 1950-51 | 3,992 | 62.64 | 80,544 | 426.01 | 2,510 | 53.19 |
| 1951-52 | 3,905 | 59.40 | 78,728 | 391.12 | 2,135 | 40.18 |
| 1952-53 | 3,045 | 40.89 | 62,847 | 237.26 | 2,001 | 34.63 |

TABLE 8—INTER-STATE TRADE (RAIL AND RIVER BORNE) OF DRY FRUITS
(Qty in maunds)

| | Imports | | | Exports | | |
|----------------|-----------|-----------|-----------|-----------|-----------|-----------|
| | 1948-49 | 1949-50 | 1950-51 | 1948-49 | 1949-50 | 1950-51 |
| Assam | 5,690 | 1,865 | 1,433 | 359 | 1,249 | 252 |
| West Bengal | 93,987 | 98,517 | 150,507 | 148,963 | 256,381 | 200,766 |
| Bihar | 122,928 | 155,839 | 198,538 | 25,404 | 29,638 | 31,674 |
| Orissa | 45,159 | 46,452 | 35,161 | 34,041 | 76,994 | 91,857 |
| Uttar Pradesh | 355,563 | 416,970 | 442,042 | 32,946 | 22,906 | 32,059 |
| Punjab | 111,705 | 110,139 | 104,399 | 37,148 | 75,328 | 103,608 |
| Delhi | 151,289 | 194,795 | 179,175 | 35,365 | 93,131 | 76,633 |
| Madhya Pradesh | 565,770 | 528,553 | 713,354 | 12,739 | 24,812 | 44,524 |
| Bombay | 1,374,643 | 1,744,701 | 1,758,117 | 1,589,975 | 1,532,933 | 1,892,379 |
| Madras | 1,258,062 | 1,587,505 | 1,796,938 | 2,083,299 | 2,851,572 | 3,229,232 |
| Rajasthan | 203,745 | 171,295 | 213,471 | 5,698 | 6,629 | 16,844 |
| Madhya Bharat | 217,813 | 242,354 | 312,001 | 43,432 | 34,917 | 27,110 |
| Hyderabad | 336,947 | 495,097 | 572,491 | 27,222 | 42,543 | 91,217 |
| Mysore | 62,197 | 57,135 | 63,699 | 761,849 | 977,556 | 605,848 |
| Kashmir | 108 | 132 | 458 | 5,317 | 169 | 607 |
| Total | 4,905,606 | 6,119,725 | 6,541,784 | 4,905,606 | 6,119,725 | 6,541,784 |

TABLE 9—IMPORTS AND EXPORTS OF DRY FISH

| | Imports | | | | Exports | | | |
|-----------------------|---------------|--------------------|---------------|--------------------|---------------|--------------------|---------------|--------------------|
| | Unsalted | | Salted | | Unsalted | | Salted | |
| | Qty (tons) | Val. (lakh Rs.) | Qty (tons) | Val. (lakh Rs.) | Qty (tons) | Val. (lakh Rs.) | Qty (tons) | Val. (lakh Rs.) |
| 1934/35-1938/39 (av.) | 1,010.8 | 1.24 | 1,686.7 | 7.93 | 7,318.9 | 25.65 | 6,766.3 | 22.90 |
| 1939/40-1943/44 (av.) | 1,645.2 | 1.03 | 73.6 | 0.13 | 9,141.5 | 47.23 | 8,639.9 | 33.64 |
| 1944-45 | 101.2 | 0.12 | 45.6 | 0.17 | 15,808.2 | 188.02 | 4,454.4 | 30.63 |
| 1945-46 | 552.4 | 0.81 | 29.9 | 0.15 | 18,721.5 | 201.42 | 5,465.2 | 46.62 |
| 1946-47 | 297.5 | 0.69 | 13.7 | 0.04 | 13,728.7 | 186.12 | 11,249.2 | 116.65 |
| 1947-48 | 586.8 | 1.46 | 36.4 | 0.19 | 8,252.0 | 102.25 | 7,524.9 | 47.00 |
| 1948-49 | 602.2 | 2.16 | 261.8 | 0.85 | 6,771.6 | 92.58 | 4,544.8 | 38.46 |
| 1949-50 | 679.3 | 2.58 | 603.1 | 4.20 | 8,995.5 | 111.81 | 5,301.9 | 58.41 |
| 1950-51 | 1,689.8 | 3.99 | 1,101.2 | 8.21 | 9,091.3 | 130.58 | 8,703.9 | 96.88 |
| 1951-52 | 2,781.8 | 7.83 | 732.3 | 5.21 | 10,088.5 | 178.66 | 10,587.5 | 131.15 |
| 1952-53 | 2,445.5 | 7.85 | 449.5 | 3.18 | 12,847.1 | 233.86 | 9,659.6 | 123.00 |



obtained mostly from Straits Settlements. India exports dry fish mainly to Ceylon and Burma.

DENATURANTS

Certain articles used for human consumption, e.g. tea, tobacco, and spirits, which are subject to customs and excise duties, are also required for industrial purposes. They are exempted from duties for industrial purposes, but only after rendering them unfit for human consumption by the addition of "denaturing" agents approved by customs and excise authorities.

Denaturants may be considered under two heads: (1) Those employed for spirits, spirituous preparations, and power alcohol and (2) those used for denaturing materials other than spirits.

DENATURANTS FOR SPIRITS

Ethyl alcohol with its many industrial applications is perhaps the most important commercial product subjected to denaturation. The requirements of an ideal denaturant for spirits and spirituous liquors, are as follows (Monier-Williams, 199) :

(1) Volatility—It should be volatile and soluble in alcohol, benzol, petrol, and in their mixtures.

(2) Taste and smell—It should impart a taste and smell sufficiently disagreeable to prevent its consumption even after dilution, sweetening, or denaturing.

(3) Elimination—It should not be amenable to separation by filtration, distillation, precipitation, or other means which can be readily applied.

(4) Detection—It should be capable of detection with ease and certainty even when present in minute quantities.

(5) Stability—It should be stable during storage and should be unaffected in contact with metals; the products of combustion should not be corrosive or possess any offensive smell.

(6) Cost—It should not be expensive and its

addition should not materially add to the price of duty-free spirits.

(7) Availability—It should be available freely and the price should not be subject to great fluctuations.

The requirements of a denaturant for power alcohol are (M'Intosh, 366) :

(1) It should add to the latent energy of the fuel

(2) It should be eliminated with the products of combustion without corroding the engine parts and it should not leave any sooty, gummy, or resinous residue

(3) It should not give rise to acids during combustion; for instance, acetone, if present in methyl alcohol denaturant, gives rise to acetic acid, and acetone-containing methyl alcohol is unsuitable for denaturing power alcohol.

The usual denaturants for spirits and spirituous preparations are methyl alcohol, pyridine, benzene, kerosene, paraffin, and pine oil. One or more of them may be employed. Some of the denaturants have an objectionable taste; others are poisonous. Alcohol may be completely or specially denatured. Completely denatured alcohol, required as anti-freeze, fuel, and lacquers solvents, contains poisonous denaturants. Pyridine satisfies the requirements of a complete denaturant. Industrial spirit required for such purposes as hair washes, liniments, and tinctures are specially denatured. Specific formulae, at least 57 in U.S.A. and 47 in U.K., have been developed to meet the needs of the manufacturing industries. Denol, Agadite, and Hydronol are among the denaturants available in the market (Brady, 242).

Caoutchoucine and pyridine are used in India for the complete denaturation of spirits. Caoutchoucine is obtained by the dry distillation of vulcanized rubber; light caoutchoucine is the fraction boiling below 200° during the redistillation of caoutchoucine. Pyridine and pyridine bases are obtained during coal tar distillation. Pyridine bases used for denaturing should be of guaranteed mineral origin. Wood naphtha obtained from pyroligneous acid is a product of the destructive distillation of wood; it contains methyl alcohol, methyl acetate, acetone, and allyl alcohol. Wood naphtha was once in use as a denaturant, but its use has now been discontinued. For certain military requirements, acetone and white spirit are used as denaturants. Specifications for light caoutchoucine, pyridine bases, and wood naphtha are given below :

Light caoutchoucine : (1) On redistilling 100 cc. of light caoutchoucine (sp. gr.²⁰ 0.835-0.860), not more than 15 cc. should pass over at or below 100°, and a total of at least 70 cc. should pass over at or below 200°; (2) it should not contain any water soluble compounds; it should be neutral to

DENATURANTS

litmus paper; (3) at least 70% of the liquid should be soluble in conc. sulphuric acid; and (4) it should not contain any appreciable quantities of moisture.

Crude pyridine bases: (1) The colour must not be darker than that obtained by dissolving 2 cc. of 0.1 N iodine solution in 1 litre of distilled water; (2) the bases should be completely soluble in water and when pyridinized alcohol is mixed with twice its volume of water, the mixture should be clear or opalescent; (3) when 20 cc. of pyridine bases are mixed with 20 cc. of caustic soda solution (d, 1.4), at least 18.5 cc. of the base should separate out after shaking the mixture several times and allowing to stand; (4) at least 50% by vol. of the pyridine bases should distil over at or under 140° and a total of 90% at or under 160°; (5) at least 9.5 cc. of N sulphuric acid should be required to titrate a solution of 1 cc. of pyridine bases in 9.5 cc. of distilled water, to give a definite blue spot on congo red paper. The blue colour should at once disappear. Congo red paper is prepared by soaking a filter paper in a solution of 1 g. of congo red in 1 litre of distilled water and drying the paper; (6) when 1 cc. of 1% solution of the bases in distilled water is added to 5 cc. of 5% solution of fused cadmium chloride, a distinct crystalline precipitate should result immediately and there should be abundant separation of crystals within 10 minutes; and (7) a white precipitate should be obtained when 10 cc. of 1% solution of the bases is treated with 5 cc. of Nessler's reagent.

Wood naphtha—(1) 30 cc. of wood naphtha should be required to decolorize 0.5 g. of bromine; (2) it should be neutral or slightly alkaline to litmus; (3) 25 cc. of wood naphtha should require at least 5 cc. of 0.1 N acid for neutralization, using methyl orange as indicator; (4) it should contain at least 72% by volume of methyl alcohol; (5) 100 cc. of wood naphtha should contain not less than 5 g. of substances (calculated as acetone), as measured by Messinger's test; and (6) it should contain not less than 1.5 g. of esters (calculated as methyl acetate).

The Indian Standards Institution has issued specifications (IS:324-192) for mineral pyridine bases and light caoutchoucine. A method has been worked out for the detection and estimation of pyridine bases in denatured spirit (Suri *et al.*, *J. Indian chem. Soc.*, 1941, 18, 273; Dunnicliff, *J. Indian chem. Soc. Industr. Edn.* 1943, 6, 56).

Light caoutchoucine required for denaturing purposes is produced in the country. Pyridine is wholly imported.

For denaturing spirit imported into India, the official procedure is to add 0.5 gal. of light caoutchoucine and 0.5 gal. of mineral pyridine bases into a drum and to pour 99 gal. of rectified

spirit of not less than 60 o.p. strength. The contents of the drum are stirred and the drum closed and rolled. The same procedure is used in distilleries for denaturing spirit for general use. Denatured spirit is issued to licensed dealers for sale to the public.

During World War II when the supply of pyridine fell short of the demand, the Council of Scientific and Industrial Research financed a scheme of research on the processing of *neem* and *neem* products for obtaining denaturants. A volatile oil obtained from *neem* cake distillate was recommended for use, but it was not accepted as official. On account of the scarcity of pyridine, a mixture of caoutchoucine (0.5%) and wood naphtha (1%) was recommended for use as an emergency measure. Many distilleries used caoutchoucine (1%) + kerosene oil (1%), or light caoutchoucine (1%) + light creosote oil (0.5%) for denaturing spirits. When the supply of caoutchoucine became limited, kiricin (0.5%), obtained by the destructive distillation of *kiri lac*, white spirit, and small quantities of rubber, was adopted as denaturant (Information from the Chemical Examiner to the Government of U.P.).

Power alcohol may be denatured with kerosene, benzene, or petrol. The statutory quantity of white kerosene oil for denaturing power alcohol is 2 vol. to 100 vol. of power alcohol; due to the scarcity of kerosene oil, the U.P. Government has provisionally permitted the mixing of 1 vol. of 'white' kerosene with 100 vol. of alcohol. Pyridine (0.5%) is used as a denaturant for power alcohol in Mysore. An admixture of 5% petrol with power alcohol at the distilleries before it is sent out has been recommended (*Rep. Panel Sugar, Alcohol and Food Yeast Industries*, Govt. India, 1946, 25).

The employment of crotonaldehyde as a denaturant for power alcohol has been recommended in place of pyridine, which is in short supply on account of its diversion for the manufacture of anti-tubercular drugs. Sweden has been using, since 1930, crotonaldehyde in a concentration of 0.6%. It has a pungent odour, acrid and burning taste, and is not very toxic; it appears to satisfy most of the essential requirements of an ideal denaturant.

Special denaturants may be used, with the previous permission of Central or State Governments, for the denaturation of spirit required in particular arts and manufactures. Soap manufacturers are permitted to use one part of castor oil and 0.5 part of caustic soda solution (1 part of caustic soda in 3 parts of water) to 100 parts of spirit by volume. Spirit denatured with 2% 'yellow' kerosene oil was permitted for the use of the Defence Department; similarly spirit denatured with 5% formalin was permitted for

use by Messrs. *Plywood Products*. Small quantities of spirits, denatured with 4% formalin, are supplied in Madras to educational and scientific institutions for preserving biological specimens. Spirit is denatured for special purposes by the addition of ammonia in the proportion of 3 vol. of liquor ammonia (25-26% by wt. of ammonia gas) to 97 vol. of ethyl alcohol in Madras (Information from the Chemical Examiner, Government of U.P.).

Preparations containing spirits, such as aeroplane dopes, collodion, hair washes, iodisers, lacquer solvents, liquid polishes, lighting fluids, liniments, and tinctures, are denatured with substances which render difficult the economic recovery of spirit in potable form. The following denaturants are in use for these purposes: acetone and acetone oils, aromatic hydrocarbons, such as benzene and toluene, animal fats, camphor, caoutchoucine, collodion, ether, iodine, turpentine, mineral naphtha, pyridine and pyridine bases, thiophene and pyrrole derivatives, and wood naphtha (Central Board of Revenue, Customs Ruling No. 5, 1931).

Additives are proposed from time to time for enabling detection of adulteration or illegal practices. Thus, wood naphtha was proposed as an additive to pyridine and caoutchoucine to facilitate testing in cases of renaturation.

DENATURANTS FOR OTHER INDUSTRIAL MATERIALS

Tea and tobacco are not generally denatured in India. In U.K., waste tea for the manufacture of caffeine is denatured to prevent its use as beverage by the addition of 100 parts of lime and one part of asafoetida to 1,000 parts of tea. Tobacco used in the manufacture of insecticides and fumigants is denatured by adding to ground tobacco or offal snuff (92.5 parts) ground moss litter (7.5 parts) and bone oil (2.5 parts) or anthracene oil (10 parts). The oil acts as deterrant and the moss litter as a tell-tale substance. Wine which has become sour is denatured with 20% commercial vinegar. Tobacco waste is denatured in Travancore by the addition of fish oil soap (1 lb.) dissolved in water (5 gal.); the solution is sprayed into the waste (200-300 lb.) and mixed (Thorpe, III, 558; *Travancore Excise Manual*, 1947, 2, 323).

Salt required for the curing of tans, hides, and skins was being denatured by the addition to salt (1 md.) of 'yellow' kerosene oil (1.5 oz.), Chlorozol Blue B.S. (0.25 oz.), soap (0.5 oz.), and water (1 lb.). With the abolition of duty on salt, denaturing has been discontinued.

PRODUCTION AND IMPORTS OF DENATURED SPIRITS

Data relating to the quantity of denaturants used in the treatment of spirits are not available. It

TABLE 1 PRODUCTION OF DENATURED SPIRIT

| | Qty (1,000 L. P. gal.) |
|------|---------------------------|
| 1938 | 2,146.8 |
| 1939 | 2,299.2 |
| 1940 | 2,575.2 |
| 1941 | 2,640.0 |
| 1942 | 2,499.6 |
| 1943 | 1,881.6 |
| 1944 | 2,560.8 |
| 1945 | 3,322.8 |
| 1946 | 3,670.8 |
| 1947 | 2,286.8 |
| 1948 | 2,949.6 |
| 1949 | 1,095.2 |
| 1950 | * 1,477.2 |
| 1951 | * 1,961.0 |
| 1952 | * 2,041.5 |

* Bulk gallons

TABLE 2 PRODUCTION OF POWER ALCOHOL

| | Qty (1,000 bulk gal.) |
|------|--------------------------|
| 1945 | 1,773 |
| 1946 | 2,398 |
| 1947 | 2,736 |
| 1948 | 3,776 |
| 1949 | 4,230 |
| 1950 | 4,497 |
| 1951 | 5,809 |
| 1952 | 7,143 |

TABLE 3—IMPORTS OF DENATURED SPIRIT

| | Qty (1,000 gal.) |
|-----------------------|---------------------|
| 1929/30-1933/34 (av.) | 880 |
| 1934/35-1938/39 (av.) | 354 |
| 1939/40-1941/42 (av.) | 378 |
| 1946-47 | 12 |
| 1947-48 | 0.2 |
| 1948-49 | 1.1 |
| 1949-50 | 3.0 |
| 1950-51 | 2.0 |
| 1951-52 | 4.1 |
| 1952-53 | 8.9 |

There were no imports during 1942/43-1945/46

is estimated that 10,000 gal. each of pyridine and caoutchoucine, and 50,000 gal. of kerosene oil are annually consumed for this purpose. An idea of the amount of denaturants consumed may be obtained from the quantity of denatured spirit produced and imported into India. Imported spirits are denatured at Indian ports by customs authorities before clearance. Tables 1 and 2 give the production of denatured spirit and power alcohol respectively. Table 3 gives the import of denatured spirit.

DIESEL ENGINE

A diesel engine is defined as an internal combustion engine so constructed that the air supplied for combustion is compressed within the engine

DIESEL ENGINE

cylinder to the point where its temperature is sufficient to ignite the injected fuel spontaneously. After ignition the charge burns and expands, thus converting the heat energy of the fuel into work (*Encyclopaedia Britannica*, 1951, 7, 348).

The compression ignition diesel engine differs from the spark ignition petrol engine in the nature of the fuel charge. In the latter, petrol and air are thoroughly mixed in the carburettor of the engine and this homogeneous mixture is introduced into the engine cylinder in the constant air: fuel ratio of 14.5:1 regardless of load. Whereas in the diesel, the fuel is injected directly as a fine spray into the cylinder, the mixing being accomplished within the cylinder itself by compressing a constant amount of air while varying the amount of injected fuel to suit the load condition. Thus the air: fuel ratio varies from c. 22:1 at full load to 85:1 when the engine is idling. The diesel engine requires a greater amount of air as compared to the petrol engine. High air: fuel ratios and high compression pressures give the diesel its advantage in fuel economy over the gasoline engine. The average thermal efficiency of the diesel is about 36% as compared with 25% for gasoline engines, 20% for steam and gas turbines, and 12% for reciprocating steam engines. These percentage figures refer to full load capacity (*Encyclopaedia Britannica*, 1951, 7, 348).

Diesel engines are employed as prime movers for marine and locomotive services. They may also be used as stationary sources of power and have proved popular with agriculturists for driving pumps, chaff cutters, threshing machines, seed cleaners, circular saws, etc. They are used also



Cooper Engineering Ltd., Satara

FIG. 14—FOUNDRY SHOWING PISTON MOULDS



Cooper Engineering Ltd., Satara

FIG. 15—MACHINING CYLINDER HEADS

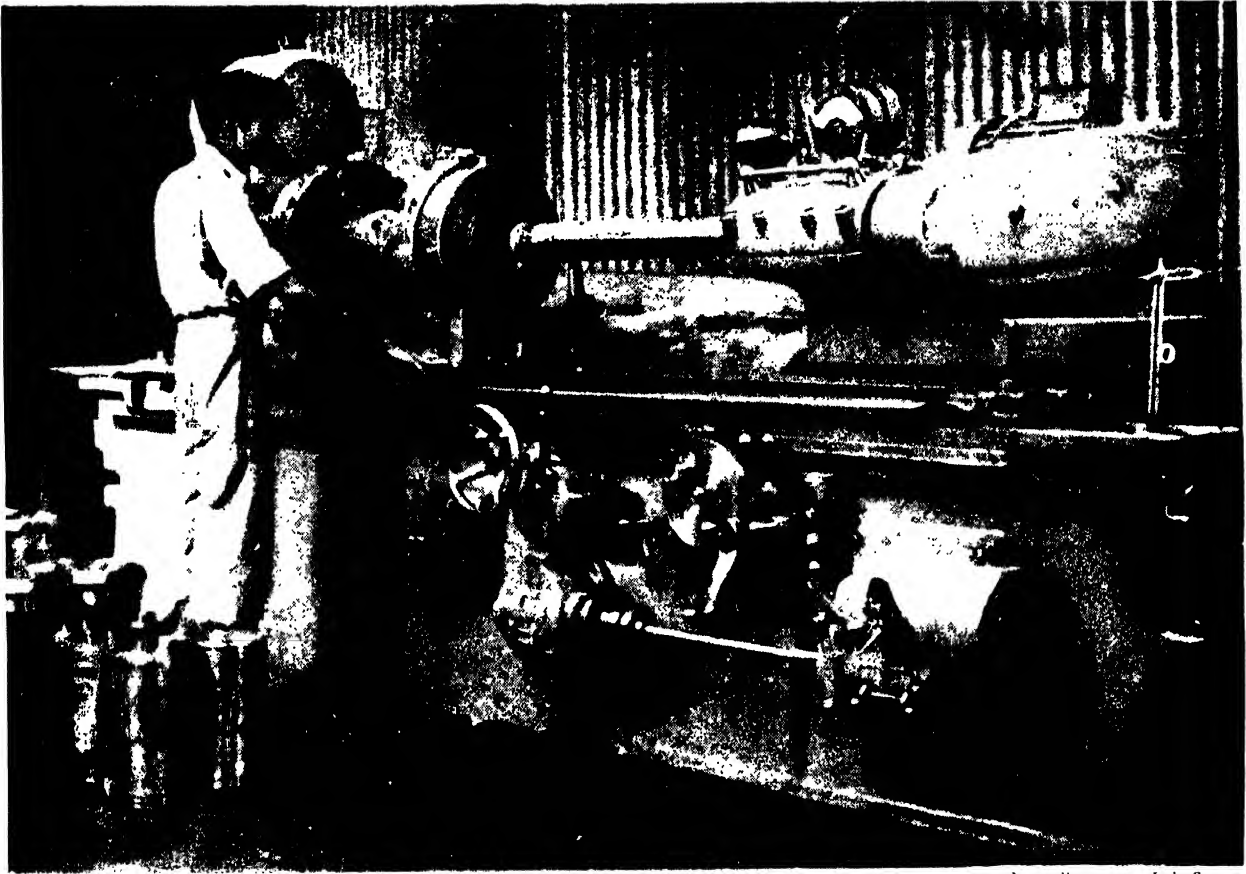
for compressing air in mines and for the generation of electricity. The advantages of diesel engines are low fuel cost, low stand-by losses, uniformly high efficiency, and simple plant lay-out.

The stationary engine is usually a heavily built unit with a piston which reciprocates in a cylinder. A connecting rod is either pinned directly into a trunk type piston or connected to a crosshead to which the piston is connected by a rod. The connecting rod bears on a crank which has bearings in the main frame. Added to these are the auxiliaries, such as valves and valve gear, fuel injection, water circulation, and starting systems. The diesel engine is more heavily built than the petrol engine and is a relatively slow-moving machine. Rotative speeds are 100-750 r.p.m. except in the case of automotive diesels which are designed for 2,000 r.p.m. and above. The fuel ordinarily employed is crude oil remaining as a residuum in the distillation still after the removal of gasoline, kerosene, and light distillates from crude petroleum: heavier residues are removed from the better grades of fuel oil.

Diesel engines are of two-cycle or four-cycle types. The fuel is injected either by blowing in and atomizing by the use of a high pressure air jet (air injection), or by spraying in through a fine nozzle tip under high oil pressure created by pumps (solid injection). The slow speed engines are either two-cycle, solid injection or four-cycle, air injection types. With a few exceptions, high speed diesel engines are of the four-cycle, solid injection type.

THE INDIAN INDUSTRY

Prior to 1932 there was no serious attempt to manufacture internal combustion engines of any type in India, although certain firms were fabricating parts of engines as replacements for imported



Cooper Engineering Ltd., Satara

FIG. 16—GRINDING THE BORE OF CYLINDER LINERS TO MICROMETER SIZE

engines. The first factory to manufacture diesel engines in this country was established in 1932 at Satara by *Cooper Engineering Ltd.* Engines of 7–30 B.h.p., of the horizontal, slow speed, open bed, single cylinder, 4-cycle, solid injection, cold starting type produced by this firm found a ready market in the country. By 1941 the annual output had increased to 300 engines. During the war years, additional sizes up to 200 B.h.p. were introduced and the output raised to 450–500 engines per annum. The present output is approximately 2,000 engines per year, covering the range 5 B.h.p. to 256 B.h.p.

The *Oriental Engineering Works Ltd.*, Lahore, were the next to take up the manufacture of diesel engines in 1933. After the partition of the country, the factory shifted to Shahdara, Delhi.

The third firm to manufacture diesel engines was *Kirloskar Sons & Co.*, Kirloskarwadi, which commenced manufacturing vertical, single and twin cylinder types of 5, 8, and 16 B.h.p. in 1938. The production of engines had to be stopped during World War II due to the stoppage of imports of certain essential components. A new

company with a capital of Rs. 25,00,000, under the name *Kirloskar Oil Engines Ltd.*, was floated in 1944. This company entered into an agreement with the *British Oil Engines (Exports) Ltd.*, London, for the manufacture of 5 to 300 B.h.p. engines. The factory which came into production in 1949, is located in Kirkee. It is proposed to increase the annual output to 6,000 diesel engines shortly. This firm was the first to manufacture vertical engines in India.

A few firms started the manufacture of diesel engines during the war on a limited scale. At present there are 5 organized firms engaged in the manufacture of diesel engines. The total annual rated capacity of the 5 firms, assessed on the basis of 8 hr. single shift and 300 working days, is estimated at about 11,325 diesel engines as against 4,770 during 1949–50 and 6,320 during 1950–51. There are other small manufacturing units but their production is somewhat irregular and negligible.

The total capital invested in the industry is estimated at Rs. 143 lakhs. The total number of workers employed in the industry is about 6,000.

DIESEL ENGINE

Raw materials—The raw materials required for diesel engine manufacture include: (1) pig iron for cylinder blocks, main frame, etc., (2) mild steel and Martin's acid steel for crankshafts and connecting rods, (3) medium carbon steel (C, 0.45–0.60%) for wear-resisting components, (4) alloy steel (of Ni, Ni-Cr, or Mo of heat-resisting specifications) for valves and fuel injection gear; and (5) bronzes (lead and phosphor bronzes, white metal) for heavy duty bearings.

All the ferrous metals required for the manufacture of diesel engines are produced in India. A part of the bronzes required for high duty bearings has to be imported. The component parts produced in the country and those imported are listed in Tables 1 and 2.

TABLE 1—DIESEL ENGINE COMPONENTS MANUFACTURED IN INDIA

| Components | Remarks |
|--|---|
| Engine bed plates, cylinder heads, cylinder liners, fly wheels, pistons, exhaust and air silencers, connecting rods, non-ferrous bearings, and bolts, valves and valve gears | .. |
| Valve springs | Obtained from firms specializing in spring manufacture |
| Piston rings | .. |
| Forced feed mechanical lubricators and other types of hand feed lubricators | Obtained from manufacturers specializing in lubricators; special types imported |



Cooper Engineering Ltd. Satara

FIG. 17—FINAL INSPECTION OF DETAIL PARTS

TABLE 2—DIESEL ENGINE COMPONENTS IMPORTED INTO INDIA

| Components | Remarks |
|--|---|
| Bolts, nuts, washers, split pins, taper pins, keys, set screws, etc. | Mostly from U.K. |
| Solid drawn steel tubing for high pressure lines of fuel injection equipment | Imported from U.K. and Germany |
| Fuel oil injection equipment | do. |
| Steel crankshafts | Manufacturing capacity of workshops in India inadequate; imported from U.K. and the continent of Europe |
| Packing and high pressure joinings | Cut to requirements from imported sheet material |

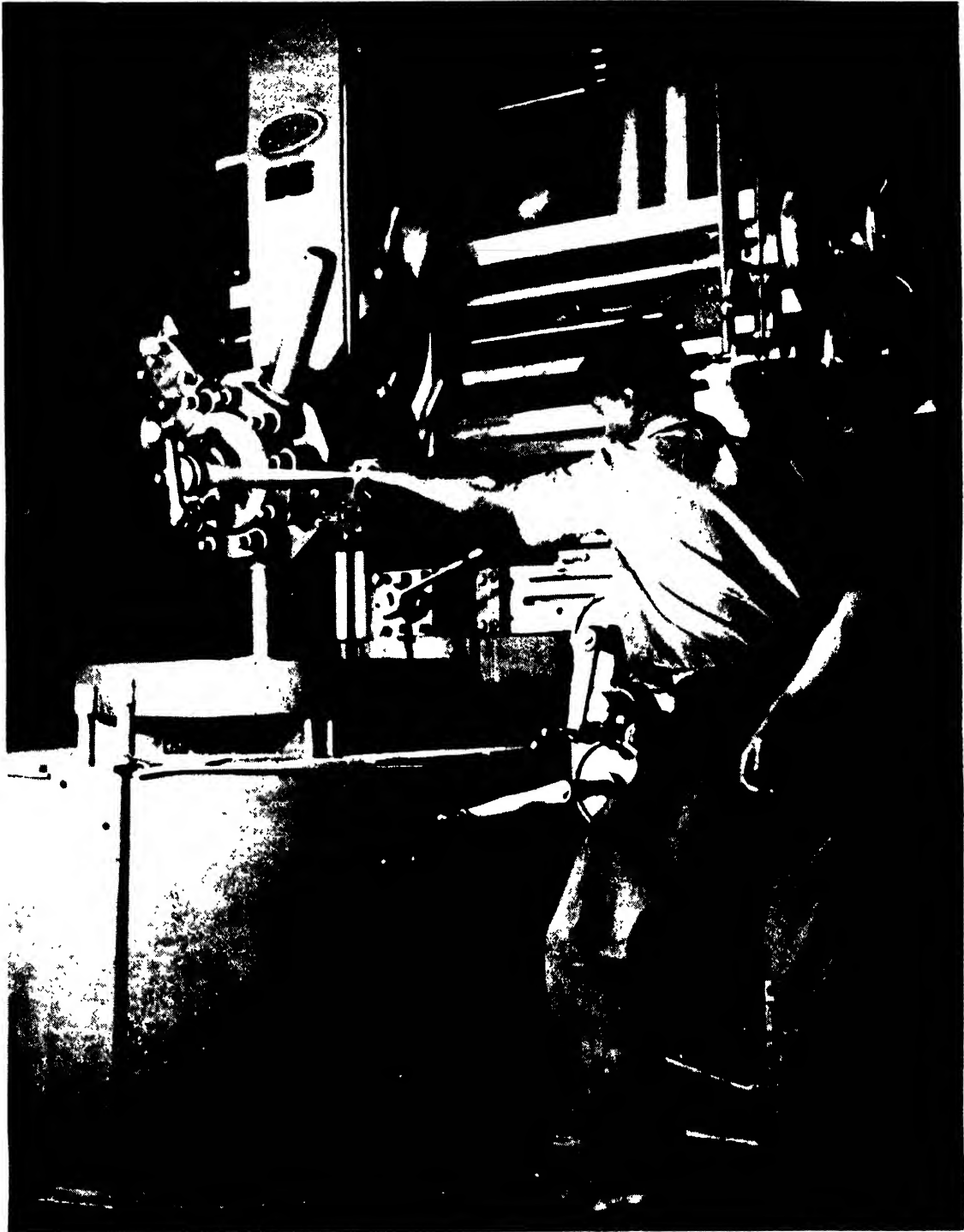
TABLE 3—RAW MATERIALS AND COMPONENTS REQUIRED FOR DIESEL ENGINES

| | 1950-51 (for 5,540 engines) (tons) | 1951 (for 7,246 engines) (tons) | Indigenous or imported |
|------------------------------------|---|--|--|
| Pig iron | 3,290 | 2,867 | Indigenous |
| Steel | 366 | 409 | do. |
| Bronzes | 131 | 68 | Indigenous and imported |
| Components : | | | |
| Fuel injection equipment | | | |
| Cam shafts | | | |
| Crankshafts (finished or forgings) | | | Indigenous and imported from U.K. and West Germany |
| Connecting rods | | | |
| Cylinder liners | | | |
| Pistons | | | |
| Springs, studs, bright bolts, etc. | | | |

Table 3 gives the raw materials consumed for the manufacture of diesel engine components during 1950-51 and 1951.

Manufacture—The *Cooper Engineering Ltd.* produce many of the castings from Meehanite, which is the name given to a number of different grades (21 in all) of high duty iron, each having a different combination of physical properties aimed towards meeting a distinctive need. Such castings have a tensile strength of 25 tons/sq. in. The *Cooper Engineering Ltd.* are the sole licensing agents for the manufacture of Meehanite metals in this country by an agreement with *International Meehanite Metal Co. Ltd.*, London. The company produces 6,000 tons of Meehanite metals per year.

For the castings, the raw materials are selected and melted in two patented design equiblast



Messrs. Cooper Engineering Ltd., Satara

MACHINING FLY WHEELS FOR DIESEL ENGINES



FIG. 18—HORIZONTAL ENGINE ASSEMBLY DEPARTMENT

Cooper Engineering Ltd., Saurashtra

cupolas. The method employed for distributing the molten metal from the cupola to the moulds depends on the quantity to be handled and on the temperature required for pouring. High strength iron should reach the moulds as hot as possible. The cores are manufactured from core blowing machines, each core being tested before use. A large percentage of the castings is made by machine moulding.

All foundry sands for moulding purposes are reconditioned in a Polford self-contained conditioning plant of 10–15 tons/hr. capacity, complete with vibrator knock out, fines separator, roller crusher, vibratory screen, conveyor, elevator, and roller miller. Portable type sand aerators and roller and paddle type sand mixers are also used.

Castings are cleaned by pneumatic chipping and fettling tools, such as grinders, tumbling barrels, and shot-blasting machines. The cleaned castings are inspected for defects and stored in rough casting stock yards to season.

The machine shop is equipped with precision planing, grinding, boring, tapping and turning machines and special jigs, fixtures, and tools to attain absolute interchangeability of parts and a high productivity rate. The parts are inspected

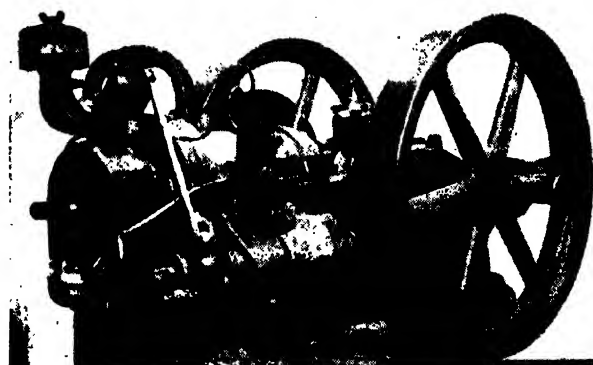
at every stage of production and also after the completion of the machining operations. Cylinder liners made from Meehanite metal are accurately machined and fitted into the engine bed plate. A special grade of Meehanite metal is used for gears, the blanks being tested for Brinell hardness after machining and before cutting the teeth; the gears are heat treated and again tested for Brinell hardness and tooth forms; they are finally checked by testing instruments.

In the sub-assembly section the various group units are assembled and tested, and passed on to the main assembly section where crankshafts and main bearings are fitted, cylinder liners inserted, and the various group units attached. The engines are finally inspected before being passed forward to test beds. Each engine is subjected to exhaustive running tests, then stripped down, cleaned, filled, painted, re-assembled, and finished, after which they are packed for despatch to users.

Development Schemes—Development schemes sanctioned by the Government of India for the manufacture of diesel engines are indicated in Table 4.

With the implementation of the new projects,

DIESEL ENGINE



Cooper Engineering Ltd., Satara

FIG. 19—AGRICULTURIST TYPE ENGINE, 5/6 B.H.P.

the annual rated capacity of the industry would increase to 29,725 diesel engines on the basis of single shift operation for 300 days.

Apart from these factories, Messrs. *Karam Chand Thapar* and Messrs. *Mahindra and Mahindra Ltd.*, also propose to manufacture diesel engines. The latter firm will shortly establish a factory near Calcutta.

TABLE 4—DEVELOPMENT PLANS FOR DIESEL ENGINES

| | Annual rated capacity (no.) |
|--|-----------------------------|
| <i>Kushbalani Russel Newberry & Co. Ltd., Bombay</i> | 5,800 |
| <i>James Beechey & Co., Bombay</i> | 1,200 |
| <i>Shree Ram Mills Ltd., Bombay</i> | 600 |
| <i>Indian Commercial Co. Ltd., Bombay</i> | 3,600 |
| <i>Hindustan Electric Co., Calcutta</i> | 3,000 |
| <i>Nandalal Bhandari & Sons, Indore</i> | 2,400 |
| <i>Faridabad Development Board, Faridabad</i> | 1,800 |

TABLE 5—PRODUCTION OF DIESEL ENGINES
(Qty in numbers)

| | 0-10 h.p. | 11-20 h.p. | 20 h.p. | Total |
|------|-----------|------------|---------|-------|
| 1946 | | | | 473 |
| 1947 | | | | 685 |
| 1948 | | | | 1,025 |
| 1949 | | | | 2,076 |
| 1950 | 2,345 | 2,190 | 61 | 4,596 |
| 1951 | 5,601 | 1,623 | 22 | 7,246 |
| 1952 | | | | 4,247 |

TABLE 6—PRODUCTION OF DIESEL ENGINES BY INDIVIDUAL MANUFACTURERS*

| | Production (no.) | | | | Type and h.p. of engines |
|--|------------------|-------|-------|--------|--|
| | 1947 | 1948 | 1949 | 1950† | |
| <i>Kirloskar Oil Engines Ltd., Kirkee</i> | .. | .. | 268 | 1,832 | Kirloskar Petter A. V. vertical 5 B.h.p., high speed |
| <i>Cooper Engineering Ltd., Satara</i> | 465 | 667 | 1,219 | 1,690 | 11 sizes; B.h.p. ranging from 8 to 64 |
| <i>Ruston & Hornby (I) Ltd., Bombay</i> | 220 | 253 | 415 | 456 | 10 h.p. and 13 h.p., horizontal, slow speed |
| <i>Kulko Engineering Works Ltd., Kolhapur</i> | .. | 93 | 120 | 125 | 8 h.p. and 12/13 B.h.p., horizontal, slow speed |
| <i>Oriental Engineering Works Ltd., Delhi-Shahdara</i> | | | 10 | 36 | 15-16 B.h.p., horizontal, slow speed |
| | 685 | 1,013 | 2,027 | 4,139‡ | |

* I. & S. Bull., 1950, 3(4), 18 † Up to Nov. ‡ For twelve months, 4,596

PRODUCTION AND TRADE

Table 5 gives the production of diesel engines in India since 1946.

At present, nearly 75% of the total output is of engines up to 10 h.p. and the rest of engines of 11-20 h.p.

Table 6 gives the annual production and types of engines manufactured in each of the five existing works.

Imports—Table 7 gives the import of diesel engines into India. Table 8 gives the imports of diesel engines, grouped according to horse power, during the years 1940, 1950, and 1951.

The major part of the imports comprises of engines up to 10 h.p.

The normal annual demand for diesel engines in India before the war was c. 5,000. The estimated demand during 1950 was 30,000 engines (below 10 h.p.). According to the Planning Commission the increase in the rate of demand for diesel engines in the next five years will be lower, as with the development of multi-purpose and power projects and the increase in the availability of hydro-electric power for all purposes, the demand will become rather limited in several areas. Taking these facts into consideration, the

TABLE 7—IMPORTS OF DIESEL ENGINES AND PARTS

| | Engines | | Parts | Total Val. (lakh Rs.) |
|-----------------------|--------------|--------------------|--------------------|--------------------------|
| | Qty (no.) | Val. (lakh Rs.) | Val. (lakh Rs.) | |
| 1934/35-1938/39 (av.) | 2,378 | 41.04 | 17.49 | 58.53 |
| 1939/40-1943/44 (av.) | 1,131 | 24.30 | 13.86 | 38.16 |
| 1944-45 | 338 | 11.78 | 15.21 | 26.99 |
| 1945-46 | 1,399 | 46.09 | 44.10 | 90.19 |
| 1946-47 | 3,202 | 137.21 | 40.22 | 177.43 |
| 1947-48 | 11,699 | 350.77 | 68.56 | 419.33 |
| 1948-49 | 16,153 | 468.99 | 93.43 | 562.42 |
| 1949-50 | 37,231 | 872.69 | 124.31 | 997.00 |
| 1950-51 | 35,571 | 683.13 | 182.22 | 865.35 |
| 1951-52 | 72,365 | 1,473.34 | 274.23 | 1,747.57 |
| 1952-53 | 17,614 | 443.20 | 196.82 | 640.02 |

TABLE 8—IMPORTS OF DIESEL ENGINES GROUPED ACCORDING TO H.P.
(Qty in numbers)

| h.p. | 1940 | 1950 | 1951 |
|-------|--------|--------|--------|
| 0-10 | 19,570 | 21,250 | 45,219 |
| 11-20 | 8,788 | 8,670 | 4,117 |
| > 20 | 3,216 | 3,014 | 6,513 |
| Total | 31,574 | 32,934 | 55,849 |

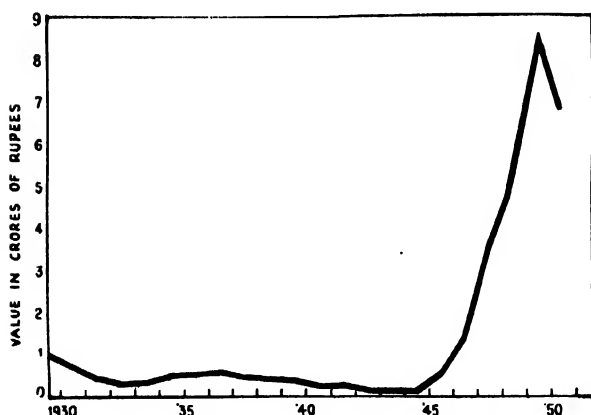


FIG. 20—IMPORTS OF DIESEL ENGINES

demand is expected to be 60,000 (below 10 h.p., 40,000; above 10 h.p., 20,000) in 1955-56.

DISINFECTANTS

A disinfectant, as the name implies, is an agent which destroys pathogenic organisms. A practical disinfectant, besides fulfilling this primary function, should not be poisonous to higher organisms, should not have corrosive or caustic action on animal tissues, and should not leave any unpleasant odour or stain in the area disinfected. A good disinfectant should also be a deodorant possessing good keeping qualities and

it should be effective against micro-organisms of widely varying types.

Sunlight and ultraviolet light, dry and moist heat, high and low frequency currents, and x-rays are among the physical agencies which are effective in sterilizing or killing micro-organisms. The chemical industry has provided a large variety of materials which have been utilized in the formulation of disinfectants.

A chemical disinfectant to be effective should be soluble in or miscible with water. Bacterial spores are more resistant to the action of disinfectants than vegetative cells. The effectiveness of a disinfectant is reduced, often markedly, in the presence of organic matter and there are undoubtedly cases where chemical disinfection is unreliable. For practical application, a disinfectant which is least affected by the presence of organic matter should be preferred. When a disinfectant is added to a bacterial suspension, which may be considered for all practical purposes as a colloidal suspension in an aqueous medium, the disinfecting principle is first adsorbed and its concentration in the adsorbed layer is influenced by the extent to which it affects the surface tension of the medium; in the next stage, it diffuses through the bacterial membrane and reduces or arrests the vitality of the organism. An effective disinfectant is one which readily penetrates into the cell walls of bacteria (Thorpe, IV, 16).

A large variety of chemicals, both inorganic and organic, have been employed for purposes of disinfection. Important among the inorganic disinfectants mention may be made of acids and alkalis; salts of copper, silver, and mercury; ozone; hydrogen peroxide; and sulphur compounds. Ozone has been employed for the sterilization of water and for keeping down the bacterial population of air in the fermentation rooms of breweries. Potassium permanganate has been used for sterilizing drinking water supplies, e.g. wells, but its use is expensive as a major portion of it is used up by inert matter before attacking the organisms. Iodine has been employed as a skin disinfectant but is not always safe and reliable, although iodoform which acts by the gradual liberation of iodine still finds use in medical practice for the dressing of wounds. Chlorine is widely used for the treatment of water supplies. In the gaseous form it is injected into the water to be treated through a suitable dosing device. It is also used in the form of bleaching powder and many proprietary disinfectants contain sodium hypochlorite. Mercuric salts rank highest among germicides for spores, but owing to their easy precipitability by a large number of substances, their action is liable to great variation.

DISINFECTANTS

Disinfectants commonly employed for general sanitation may be considered under 4 groups, viz. (1) coal tar derivatives, including soluble cresylic and emulsifiable tar oil sub-groups; (2) synthetic phenolic disinfectants—those derived from alkyl, aryl, alkaryl, and halogenated phenol derivatives; (3) pine oil disinfectants; and (4) quaternary ammonium salts. The acridine derivatives (Acriflavine and Proflavine), which do not fall under any of the above mentioned groups, have lately acquired importance, particularly for wound dressing.

(1) *Coal tar derivatives*—Coal tar disinfectants are extensively used for sanitation purposes—for drains, floors, stables, etc., and are prepared from coal tar distillates containing high boiling tar acids. Their germicidal power is due to the higher homologues of phenol present in tar acid fractions. Coal tar disinfectants are much less affected in contact with organic matter than hypochlorites.

Cresols are but slightly soluble (1 part in 50) and xylenols practically insoluble in water. They have to be, therefore, emulsified for use as disinfectants.

The emulsified products can be diluted to any desired extent for use and dilute solutions leave no stain and are easily washable. Emulsification increases the effective concentration of the active principles around the bacteria and the presence of the turbid germicide is rendered obvious to the eye.

The factors which influence the suitability or otherwise of a tar distillate for disinfectants are its specific gravity, ease of emulsification, colour of emulsion, and naphthalene content. The specific gravity should be such that, when combined with other ingredients, the resulting fluid has a specific gravity near unity.

A large range of coal tar disinfectants, varying in composition and in the method of preparation, are marketed. They may be grouped into (1) emulsified products—Black Fluids and White Fluids; and (2) preparations which on dilution with water remain more or less clear, e.g. Lysol. Commercial white and black fluids have a Rideal-Walker (R.W.) coefficient of 1-25. The R.W. coefficient of Lysol is 1.6-2.9 (Thorpe, IV, 33).

Black fluids are more common and are prepared from cresylic creosote (20-40% cresylic acid) with or without the addition of high boiling (b.p., 220-250°) tar acids. Creolin and Jeyes Fluid are two of the disinfectants of this type. They are emulsified with soft soap made from rosin, castor oil, and linseed oil. The composition of a typical black fluid disinfectant is as follows: cresylic creosote (35% tar acids), 55; rosin soap, 30; and water, 15% by weight. Low grade black fluids (R.W. coeff., 0.5-3.0) are made from cresylic creosote containing 20-40% tar acids.

White fluids contain a comparatively high percentage of high boiling tar acids. An emulsifying agent (e.g. Turkey Red Oil) and a stabilizer (e.g. gelatine, casein) are incorporated. The selected emulsifier and stabilizer are mixed with water and heated; tar acid is run in slowly under vigorous stirring and the resulting mixture is passed through a colloid mill before storing. White fluids contain more water (minimum, 40%) than black fluids. The maximum limit to the water content is not specified; white fluids containing 90% water are available in the market. The composition of a typical white fluid is as follows: high boiling tar acids, 40; Turkey Red Oil, 5; gelatine, 2; and water, 53%.

Lysol (*Liquor Cresolis Saponatus*, *Saponified Cresol*) is a standardized coal tar disinfectant of the white fluid group. It contains 50% cresols (*para* and *meta*), complying with the specifications for Cresol B.P., dissolved in a vegetable oil soap, generally potash soap. Linseed oil is used for saponification in U.K. and corn, cottonseed, soyabean, and other oils (sap. val., not greater than 205; iod. val., not less than 100) are used in U.S.A. Cresol is emulsified with soap and diluted with water to the required volume. A typical formula for Lysol is the following: cresol, 500 cc.; linseed oil, 180 g.; caustic potash, 42 g.; and water, to make 100 cc. (B.P., 318).

(2) *Chlorinated phenols*—The germicidal value of xylanol is about 5 times that of phenol; the addition of a single chlorine atom to the xylanol molecule increases the germicidal value 10 times and, at the same time, reduces the toxic and irritating action. Chlorinated xylenols can be easily emulsified with freshly prepared solutions of castor oil soap and rectified spirit. The mixture is perfumed with essential oils and diluted with water. Dettol, well known among the disinfectants of this class, contains 5% chlorinated xylanol; it does not affect the skin or mucous membrane even in high concentrations. Disinfectants of this class are well suited for dressing wounds, gargling, and for sterilizing surgical instruments.

(3) *Pine oil disinfectants* are emulsions of pine oil in rosin soap solution. They form milky suspensions when shaken up with water; they are non-irritant and are useful as deodorants and disinfectants for cleaning sinks, drains, carpets, rugs, wood works, garbage cans, floors, etc. A typical formulation for this type of disinfectant is the following: pine oil, 5.5 lb.; rosin, 2 lb.; caustic soda, 0.125 lb.; and water to make up 1 gal. Pine oil and rosin are heated together until the rosin dissolves. The solution is cooled to 176°F. and caustic soda solution added under stirring. The mixture is diluted with water to 1 gallon. A composition suitable for spraying contains: thymol, 1 lb.; pine oil, 2.75 lb.; oil

spike lavender, 2.75 lb.; potassium permanganate, 1.6 oz.; isopropyl alcohol, 6-7 gal.; and water to make up 8-9 gal.; thymol and oils are dissolved in isopropyl alcohol and mixed with an aqueous solution of potassium permanganate. It is well adapted for use in homes and hospitals (Belanger, 24).

(4) *Quaternary ammonium compounds*, often called cationic soaps, are ammoniated derivatives of oils, fats, and waxes. Compounds of the type alkyl-dimethyl-benzyl-ammonium chloride and dialkyl-monomethyl-benzyl-ammonium chloride, in which the alkyl group may be saturated or unsaturated, those derived from cyclic amines, such as pyridine, picoline, and lutidine, of which cetyl pyridinium chloride is an example, and those containing an aromatic ring in the long chain, such as *para*-tertiary octyl-phenoxy-ethoxy-ethyl dimethyl benzyl ammonium chloride, sodium cetyl dodecyl amide lauryl ester of glycine hydrochloride, etc. have attained commercial importance (Palit, *Indian Soap J.*, 1950, 15, 181).

Quaternary ammonium compounds are soluble in water and are effective in 1:1,000 dilution. They show increased activity in the alkaline range (germicidal power, 300-400 times that of phenol). They are relatively non-toxic, non-corrosive, colourless, tasteless, and odourless in the usual concentrations employed. They are used in surgical practice and for general sanitation in hospitals, restaurants, and breweries. They were extensively used during World War II for the disinfection and dressing of wounds. Their activity is greatly reduced in the presence of nitrogenous organic matter (Prescott & Dunn, 1953).

Testing—The standard method used for evaluating disinfectants is the determination of Rideal-Walker coefficient or phenol coefficient, using phenol (1:95, 1:105, 1:110, or 1:115) as reference material, and a 24-hr. culture of *B. typhosus* in R.W. broth as the test organism. The R.W. coefficient is obtained "by dividing that dilution of the disinfectant which shows life in 2.5 and 5 minutes but no life thereafter, by that dilution of carbolic acid which shows life in 2.5 and 5 min. but no life thereafter." This test has been much criticized and although modifications have been suggested from time to time, no other test has yet appeared to replace it. The test has been criticized firstly on the ground that *B. typhosus*, which is used as the test organism, does not give results typical of other pathogenic organisms and secondly, that the test is carried out in the absence of organic matter, while in practice organic matter is invariably present; the test compares a disinfectant with phenol in its effectiveness to kill *B. typhosus* under certain labora-

tory conditions and bears little relationship to the actual prevailing conditions (Thorpe, IV, 32).

In the Chick-Martin test, the effectiveness of a disinfectant against *B. typhosus* is examined in the presence of human faeces (dried on a water bath, ground, and passed through a 130-mesh sieve). In a modification of this test, a yeast suspension is employed. The test is still arbitrary as it gives no indication of the germicidal power in the presence of a wide variety of organic materials. A modified Rideal-Walker method is adopted in U.S.A. (*Circ. U.S. Dep. Agric., Fd Drug Admin.* No. 198, 1931).

The bactericidal efficiency depends on the concentration of the disinfectant. For general disinfection, a phenol solution of 1 in 20 parts of water is considered adequate. The dilution for disinfectants required for the same purpose is determined by multiplying the R.W. coeff. by 20, e.g. the dilution for a disinfectant with R.W. coeff. 12, is 1 part in 240 parts of water.

THE INDIAN INDUSTRY

Black disinfectants are manufactured on a large scale in India and marketed under the trade name Phenyle. The principal manufacturers are: *Shalimar Tar Products Ltd.*, Lodna (Jharia), *Bararee Coke Co. Ltd.*, Kusunda (Jharia), and *Bengal Chemical & Pharmaceutical Works Ltd.*, Calcutta, who are also distillers of coal tar. Messrs. *Standard Chemical & Pharmaceutical Co.*, Bombay, produce both black and white fluids with R.W. coeff. 18-20, using coal tar derivatives imported from U.K. to supplement the creosote oil available to them from *Bombay Gas Co.*, Bombay. A large number of chemical manufacturers prepare and market phenyle from coal tar fractions purchased from tar distillers. White fluid is occasionally produced by *Bararee Coke Co. Ltd.*

Three types of black fluid are generally manufactured in India. Class I fluids contain low concentrations of creosote oil and Class III, high concentrations; Class II fluids are intermediate between the two. Typical recipes of soap base compositions used for the three classes are: *Class I*—Rosin, 80; linseed oil, 10; and castor oil, 10; or rosin, 70; linseed oil, 5; castor oil, 10; and cottonseed oil, 15; *Class II*—Rosin, 30; linseed oil, 40; and castor oil, 30; or rosin, 20; linseed oil, 30; castor oil, 45; and cottonseed oil, 50; *Class III*—Rosin, 15; linseed oil, 35; and castor oil, 50; or rosin, 10; linseed oil, 25; castor oil, 50; and cottonseed oil, 15. The ratios of soap: water to creosote in the 3 classes of products are: *Class I*—1:1 to 6:1 to 2; *Class II*—1:1 to 4:1 to 5; *Class III*—1:1 to 4:1 to 6 (Datta *et al.*, *Bull. Dep. Industr. Beng.*, No. 81, 1939, 7).

DISINFECTANTS

Soft soap is prepared by adding a boiling solution of caustic soda (30° Tw.) to a mixture of castor oil and molten rosin. The proportions of the constituents are adjusted to give 1.0-1.5% excess of alkali. The soft soap thus obtained is dissolved in hot water and creosote oil added. The mixture is stirred to give a homogeneous liquid. The fluid thus obtained is dark brown or black in colour, indistinguishable in appearance from the creosote oil used in its preparation. On dilution with water a milky white stable emulsion is obtained. Black fluids are miscible with soft and moderately hard water but not with salt water or urine.

White disinfectants have the same R.W. coeff. as black fluids. They are miscible with sea water and urine and are particularly suitable for use in hospitals, ships, etc. They are not as stable in storage as black fluids and are liable to creaming. For ensuring stability, the particle size of the emulsion should be small. A fairly stable preparation with 50% high boiling tar acid homologues of phenol contains c. 250,000 oil particles per cu. mm. and the specific gravities of the disperse and aqueous phases are approximately equal.

Specification No. G/Misc. 87-A for coal tar disinfectants requires that white fluids shall show perfect stability and homogeneity after two months' storage. They shall be miscible in all proportions with distilled water, "artificial hard water" (0.657 g. of crystallized A.R. calcium chloride in 1 litre of solution), and "artificial sea water" (27 g. of sodium chloride and 5 g. of crystalline magnesium sulphate in 1 litre solution) to give a uniform emulsion which shall not show any oily separation at the surface or undue deposition on standing for 6 hr. at room temperature.

Black fluids shall show perfect stability and homogeneity after storage for 12 months. They shall be miscible with distilled water and artificial hard water in all proportions up to 20% to give a uniform emulsion which shall not show any oily separation at the surface or undue deposition on standing for 6 hr. at room temperature.

The undiluted disinfecting fluid shall not have a caustic or blistering effect on human skin if left in contact for a period not exceeding 3 minutes. When diluted for use, they shall be non-poisonous to human beings and shall not have any destructive action on linen, leather, wood, or metal (unpainted).

White fluids shall emulsify when poured direct into urine, other organic fluids, and black fluids. White disinfecting fluids shall possess a R.W. coeff. of not less than 10 and black disinfecting fluids, not less than 5 when tested by the

method laid down in the British Standard Technique for the determination of R.W. coeff. for disinfectants (B.S.S. No. 541) except that the Rawlings strain of *B. typhosus* is to be used in place of the Lister strain. A tolerance of 20% may be allowed.

The inner surface of the containers in which disinfectants are packed shall be such as to preclude the possibility of hydrogen gas generation during storage.

Disinfecting fluids shall be supplied in non-returnable 1, 5, 10, or 40 imp. gal. composite steel drums or containers, either electrically welded or seamed, and double soldered at all joints as required by the purchaser. The bung of drums and containers should preferably be closed with a patent capsule or seal to prevent leakage and substitution of supply during transit.

A description of contents shall be stencilled on each container together with the maker's name, the trade mark, and the year of supply and such other marks as may be required by the purchaser. Where the fluid is likely to have caustic or blistering effect on the human skin when left in contact for more than 3 minutes, the containers shall be clearly labelled to this effect, warning the staff to use care in handling.

Dettol—Dettol is manufactured by Messrs. Parry & Co., Ranipet. The chief antiseptic principle, a mixture of isomers of chlorinated xylol, is imported. A solution of the antiseptic principle is blended with graded terpene hydrocarbons containing α - and β -pinenes in certain proportions. The resulting solution is completely miscible with water forming a permanent emulsion. The R.W. coeff. is fixed at 3. Dettol so prepared is filtered through a neutral medium into a large storage tank from which it is filled into bottles through vacuum fillers.

Glass bottles with plastic caps are employed as containers. The cap is heat sealed, the bottle labelled and packed in cartons. Large tin containers with screw lids are also used.

Dettol is an excellent deodorant. It is non-poisonous and is well tolerated even in high concentrations on skin and mucous membrane. It remains germicidal even in the presence of large quantities of blood and pus. As the active constituents are non-volatile, the germicidal action is lasting. It is claimed to be effective against *Staphylococcus aureus* and *Streptococcus pyogenes* in the presence of blood serum and pus.

A dilute solution of Dettol is applied as disinfectant for cuts and wounds, and for general sterilization. It can be sprayed for disinfecting rooms. It is used in midwifery.

Production and Trade—Table 1 gives the production of phenyle type of disinfectants in India during 1946, 1947, and 1948.

DISTILLED LIQUORS

TABLE 1—PRODUCTION OF PHENYLE TYPE OF DISINFECTANTS*

| | Qty (1,000 gal.) | | |
|----------------------------------|---------------------|--------------|-------------|
| | 1946 | 1947 | 1948 |
| West Bengal | 149 | 184 | 155 |
| Bombay | 101 | 141 | 39 |
| Uttar Pradesh | 1 | 9 | 4 |
| Bihar | 168 | 41 | 14 |
| Madras, Punjab, Delhi & M.P. | 1 | 2 | 3 |
| Total Qty | 420 | 377 | 215 |
| Total val. (lakh Rs.) | 9.13 | 11.17 | 7.02 |

Second Census of Manufactures in India 1947, 1950, 560; Third Census of Manufactures in India 1948, 1951, 562, 569

TABLE 2—PRODUCTION OF DISINFECTANTS, 1949-1952

| | Qty (gal.) |
|------------------|---------------|
| 1949 | 436,300 |
| 1950 | 492,111 |
| 1951 | 388,121 |
| 1952 (Jan./Aug.) | 152,524 |

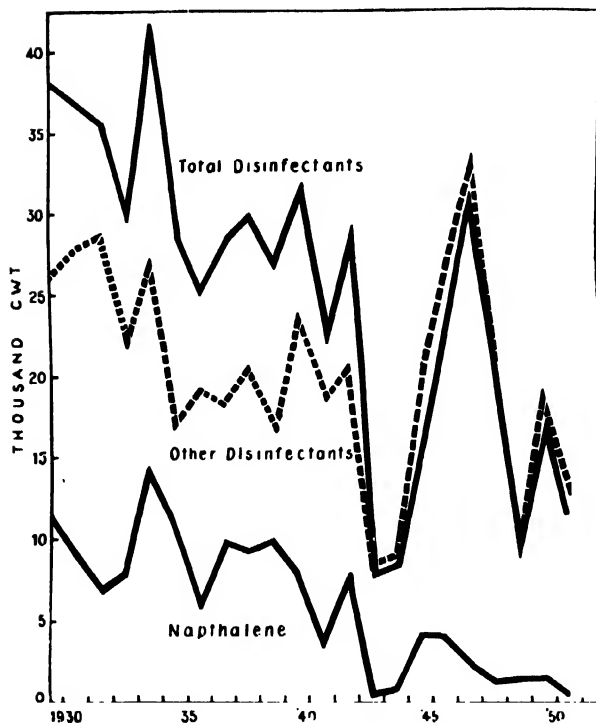


FIG. 21—IMPORTS OF DISINFECTANTS

TABLE 3—IMPORTS OF DISINFECTANTS*

| | Qty (1,000 cwt.) | Val. (lakh Rs.) |
|-----------------------|---------------------|--------------------|
| 1934/35-1938/39 (av.) | 18.45 | 5.27 |
| 1939/40-1943/44 (av.) | 15.97 | 5.22 |
| 1944-45 | 16.52 | 8.11 |
| 1945-46 | 22.42 | 11.60 |
| 1946-47 | 31.78 | 30.90 |
| 1947-48 | 21.15 | 11.18 |
| 1948-49 | 9.00 | 8.43 |
| 1949-50 | 22.51 | 24.10 |
| 1950-51 | 11.86 | 14.80 |
| 1952-53 | 41.37 | 38.66 |

* Does not include figures for naphthalene

Other types of disinfectants valued at Rs. 4.08, 7.14, and 10.40 lakhs were produced in India during 1946, 1947, and 1948 respectively.

Table 2 gives the production of disinfectants during the period 1949-52.

Table 3 gives the imports of disinfectants into India, mostly from U.K. and U.S.A.

DISTILLED LIQUORS

Whisky, brandy, rum, and gin are among the distilled liquors of commerce, known all over the world. They are obtained by the distillation of fermented saccharine liquids and contain, besides alcohol, certain 'congeneric' substances produced during fermentation and storage which, excepting in the case of gin, are responsible for their characteristic flavour and bouquet.

Whisky (alcohol content, 85°-100° proof) is obtained by the distillation of a fermented mash of cereal grains saccharified by the diastase of malt. Whisky contains acetic, valeric, and propionic acids and their ethyl and amyl esters, aldehydes, such as furfural and acetaldehyde, and fusel oils (Valaer, *Industr. Engng Chem.*, 1940, 32, 935).

Scotch Whisky, prepared from barley malt alone, is characterized by a smoky odour, traceable to the use of peat for firing malt drying kilns. Irish Whisky is prepared from barley malt to which wheat, oats, and rye are added. A mixture of rye or barley malt with unmalted rye or corn is used in U.S.A. for preparing the mash; the spirituous liquor obtained is known as Rye Whisky and Bourbon (corn) Whisky. Commercial whiskies are often 'dosed' with small amounts of additives, such as peach juice, glycerine, caramel, tea, coumarin, orris root, dried prunes, sherry wine, vanilla, caraway seed, cinnamon, and cloves, for improving the flavour (von Loesecke, 417).

Imitation whisky is made from ethyl alcohol by colouring and flavouring.

Brandy (alcohol content, 90°-100° proof) is a

DISTILLED LIQUORS

distilled product from fermented grape wine (Valaer, *Industr. Engng Chem.*, 1939, **31**, 339).

Brandy is a yellowish brown liquid with a sweet, smooth ethereal flavour and fine bouquet. The flavour is due to the presence of capric (oenanthic) ester and other volatile constituents of wine. Among the constituents present are: esters of acetic, butyric, and valerianic acids, volatile oils, tannin, fixed acids, and colouring materials. It is used as a stimulant in cases of suspended animation or exhaustion.

The best brandy, known as Eau-de-vie-de-Cognac, is prepared in Western France, especially in the Cognac district. It is prepared from the fermented juice of a variety of grapes with low sugar content. The product obtained from high quality white wine is of the first quality. Inferior qualities are made from second grade, spoiled, or soured wine, grape pomace, and wine lees. Apples, peaches, apricots, black berries, cherries, raisins, oranges, etc. may also be used; the brandy obtained is known by the name of the fruit used. Apple brandy, known as Apple-jack, is prepared in California; the esters responsible for its flavour are amyl and isoamyl acetates and ethyl and amyl valerates. British Brandy is prepared by redistilling grain spirits with flavouring materials. Hamburg Brandy, manufactured in Germany, is made from potato or beet spirit and flavoured to imitate grape brandy. Imitation brandies are made by 'cutting' strongly flavoured brandy with diluted rectified grain alcohol, colouring, and sweetening with caramel and cane sugar syrup, and 'dosing' with Lees oil or an extract of oak wood chips. Extract of cedar wood chips, bitter almonds, stored plums, and walnut shells are often added to give aged characteristics and herb-like flavours. Sometimes orris root, coumarin, cinnamon, pekoe tea, or vanilla are added (Herstein & Gregory, 143).

Rum (alcohol content, 85°-100° proof) is a yellowish brown liquor of fine bouquet with a sweet, smooth, alcoholic taste and a flavour which cannot be successfully imitated (Valaer, *Industr. Engng Chem.*, 1937, **29**, 988).

Rum is obtained from fermented sugar cane products. The flavour is due to a mixture of esters, chiefly ethyl butyrate, formate, and acetate. Genuine rum exists in two qualities, Jamaica Rum and Demerara Rum. The first is obtained by slow fermentation (10-12 days) and the second by rapid fermentation (36-48 hr.) of sugar cane molasses. Imitation rum, made in Germany, is obtained from grain or beet spirit by artificial flavouring.

Gin (alcohol content, 85°-100° proof) is a sweetened or unsweetened grain spirit flavoured with the essential oil of juniper (*Juniperus communis*) berries. It differs from other distilled

liquors in that it derives its flavour from an additive rather than from a product of fermentation.

Geneva or Hollands is a spirit which is prepared from a mixture of malted barley, rye, and barley in equal proportions. English Gin is a patent-still spirit made from 15 parts of maize, 3 parts of malt, and 2 parts of rye. Sweetened gins are prepared by adding small quantities of glycerine and sugar syrup to plain gin. Plymouth Gin, which has a characteristic ethereal flavour, is prepared by adding a little sulphuric acid before rectification. Low grade gin is made from alcohol prepared from molasses or other fermentable material in patent-stills. The spirit so obtained is redistilled in pot-stills with juniper berries or other additives, such as orange and lemon peels, angelica, coriander seeds, cardamom seeds, caraway, liquorice powder, almond, cassia buds, nutmeg, orris root, sweet fennel, and turpentine. The peculiar flavour of gin is due to α -pinene, camphene, cadinene, and terpenoids contained in juniper oil. Gin is sometimes made by flavouring patent-still spirit with essential oils (Thorpe, V, 532).

Besides the above, a large number of distilled liquors are made in different countries. Mention may be made of country liquors produced in India, Arrack in Siam, Malaya, Jamaica, Ceylon and India, Vodka in Russia, and Kornbranntwein and Schnapps in Europe. The Indian country liquors are distilled from fermented molasses or mahua (*Madhuca indica*) and compounded with flavouring agents. Arrack is obtained by the distillation of toddy or a mixture of toddy with fermented rice and molasses. It is a yellow to light brown liquor with a rather sour taste and aroma. The flavour resembles that of rum when fermented molasses are used in the preparation. Liqueurs are made by adding sugar with flavouring and colouring materials.

TYPES OF STILL

Both pot- and patent-stills are used for the manufacture of distilled liquors. Pot-still spirits contain an appreciable amount of volatile acids, furfural and other aldehydes, and higher alcohols. The volatile acid, which usually distils over, is acetic acid; it may be eliminated or reduced by carrying out the fermentation under aseptic conditions with yeast free from bacterial infection and distilling the fermented wash soon after fermentation. The aldehydes commonly present are acetaldehyde and furfural. Acetaldehyde is formed by the oxidation of alcohol and its concentration can be kept low by eliminating all chances of air coming into contact with alcohol vapours. Furfural is formed by the combined action of heat and acids on the unfermented

pentoses present in the mash. It has a far more deleterious effect than any of the impurities present in the liquors. Fusel oil or higher alcohols are produced chiefly during fermentation.

Pot-still distillates being of low strength are usually redistilled; the second distillation also eliminates undesirable constituents. The second distillate is usually collected in three fractions, the first and the last fractions, called respectively foreshots and tailings, being collected in the same receiver and redistilled along with a subsequent charge to recover alcohol. Foreshots are rich in volatile acids and the tailings, in fusel oil. The middle runnings are collected separately and used for potable purposes.

Pot-stills are used in the preparation of high quality potable liquors. The simple still is a retort or kettle with a convex or dome-shaped cover (breast) which acts as a rectifier. Attached to the cover is a goose-neck which conveys the alcoholic vapours to a worm condenser immersed in cold water. The condensed vapours are collected in a receiver. Various modifications of the primary still are in use. In most of them the fermented wash is pre-heated by the latent heat of the condensing vapours before it enters the still, thereby securing heat economy. Some are provided with rectifying columns. Pot-stills may be heated by direct firing or by steam coils or they may be steam-jacketed.

Pot-stills are preferred for Scotch and Irish whiskies and French brandies as they ensure the presence of high concentrations of congeners. In U.K., whisky is prepared in improved pot-stills. Irish whisky is prepared in large pot-stills with short heads connected to a pipe immersed in water and acting as a rectifier. Pot-stills are also used for the manufacture of Apple-jack, rum (especially in U.S.A.), and gin (for redistilling with juniper berries).

Patent-stills (cf. With India, Pt. I, 55) are flexible in operation. Rectification can be regulated to any desired degree and the presence of congeneric substances ensured in the distillate. The spirit is always obtained at a high proof and the product has therefore to be diluted to give the final spirit. Gin and rum are usually made in patent-stills. Scotch and Irish whiskies obtained by patent-still distillation are used for blending with pot-still products. Patent-stills have come into use in U.S.A. and in some parts of U.K. for the production of whisky. They enable the recovery of 90% of the alcohol as whisky of 50-75% o.p. The product is diluted to the desired degree before aging. Brandy is prepared in U.S.A. in patent-stills. Beverage brandy is distilled at 140°-160° proof, while brandy for fortification is taken from the still at 190° proof. They are

diluted to the desired degree prior to aging (Herstein & Gregory, 112; von Loesbecke, 410).

AGING

Excepting gin, all other liquors are aged for periods extending to several years in special wooden casks to remove the raw taste and odour, and to produce a spirit with the desired body, flavour, mellowness, and bouquet. The 'proof' also increases during aging. There is an increase in the solid content and colour due to the extraction of tannin and resinous bodies from the wood. The congeners react with each other and with alcohol to impart to the liquor the characteristic flavour and bouquet. Whisky is aged by storing in charred or uncharred oak barrels. Rye whiskies in U.S.A. are aged in charred barrels for 1 to 5 years in bonded warehouses at 65-85°F. and 65-70% humidity. There is no improvement in quality after 10 years' aging and no marked improvement after 4 to 6 years. Highly aged whiskies are expensive on account of their bouquet; also losses suffered in bulk during storage are compensated by enhancing the prices (Shreve, 665; Herstein & Gregory, 128).

French brandy is aged in uncharred white oak barrels for 4 to 5 years—sometimes for 20 years or more. Cheap brandies are not aged; they are decolorized with active carbon and coloured with caramel. Tea infusion is added to give the required astringency.

Freshly prepared, heavy bodied rum is unsuitable for beverage purposes. In U.S.A., it is diluted to 100° proof and aged in oak vessels for c. 4 years. Weak bodied rums are seldom aged.

Whisky can be 'artificially aged' by treatment with gaseous oxidants, e.g. air, oxygen, and ozonized air, under irradiation by ultra violet light, or light from neon lamps, or by electrolytic treatment (Herstein & Gregory, 129).

Aged liquors are blended to produce uniform brands to meet consumers' requirements before bottling. The blending is a specialized art in which judgement of the expert is the sole criterion. In blending whiskies, two or more 'straight' whiskies are mixed according to secret formulae and the mixture 'dosed', coloured, and aged before bottling.

THE INDIAN INDUSTRY

Distilled liquors are produced from fermented molasses, palmyra jaggery, and mahua flowers on a small scale in every part of the country. Juices tapped from date, palmyra, coconut, and *nipa* palms are also employed in some localities. The saccharine materials are fermented for 3-7 days in earthen pots with yeasts naturally associated with the raw materials and the fermented washes are distilled in earthenware

DISTILLED LIQUORS

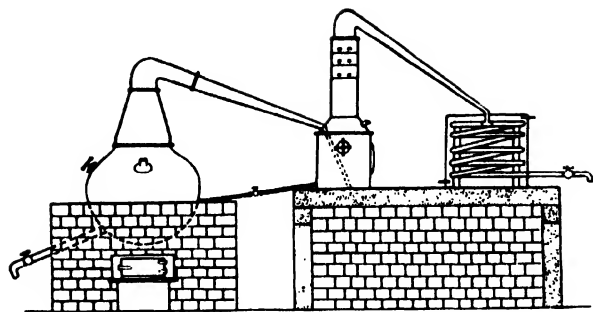


FIG. 2—POT-STILL

pot-stills provided with improvised condensers and receivers. Improved pot-stills of copper (Fig. 22) provided with efficient cooling systems have largely replaced the inefficient pot-stills during the past two or three decades and fermented washes are subjected to double distillation to produce spirits free from fusel oil and other impurities.

Two types of distilled liquors are produced in this country: 'country' spirits, and 'foreign' spirits. The former, containing 80° proof alcohol, is available in plain, spiced, and sophisticated grades. Foreign spirits produced in India are whisky, brandy, rum, and gin. The first three contain at least 75° proof spirit and gin, about 65° proof spirit. Indian spirits are stronger than the corresponding English spirits.

Country liquors are produced in small-sized distilleries using pot-stills. Both country and foreign spirits, using improved pot-stills and patent-stills, are produced in modern distilleries.

Country liquors—The product obtained by straight distillation of fermented liquors in pot-stills is of 25°–30° proof. It is, therefore, repeatedly distilled to obtain a spirit of standard strength (80° proof). Rectified spirit obtained by the use of patent-stills and diluted to 80° proof is marketed as Plain Country Spirit or White Rum.

Spiced spirits are made in Punjab, Bombay, and, to a small extent, in Ajmer-Merwara, from both pot- and patent-still spirit. The flavouring materials employed are rose petals, tejpat (*Cinnamomum tamala*), cardamom, dalcchini (*C. zeylanicum*), nutmeg, saffron, keora (*Pandanus tectorius*), fennel, coriander, ginger, mund (*Sphaeranthus indicus*), nim (*Azadirachta indica*), peppermint, mango, jasmine, khas (*Vetiveria zizanioides*), sweet lemon, apple, pineapple, raspberry, almond, musk, and amber. Spiced liquors are often sweetened with sugar. For preparing Orange Spiced Spirit, orange peel with small proportions of sandal, khas, and mulatti (*Glycyrrhiza glabra*), is added to the charge in the pot-still during redistillation. The product is coloured orange. Rose petals and

spices are used to give Rose Spiced Spirit and the product is coloured red. Patent-still spirit is diluted with water before redistilling.

Spiced spirits are sometimes obtained from rectified spirit by the 'cold process', i.e. by the addition of essences and colours to resemble rose, orange, apple, keora, pineapple, etc.; the resulting product is of inferior quality and is known as Sophisticated Country Spirit.

Foreign spirits—The first modern distillery to produce rum (20–30 o.p.) was erected at Rosa near Shahjahanpur (U.P.) about the year 1835. The product acquired considerable reputation and was in great demand in Bengal and Bombay. By 1900, private distilleries located in Simla and Amritsar were producing brandy, white rum, genuine rum, and gin, from molasses spirit flavoured with imported essences, and whisky from malt as well as from molasses spirit. Messrs. Parry & Co., Madras, started production of foreign spirits in 1917. Production of potable liquors increased during World War I.

Large quantities of imitation foreign liquors, especially whisky and brandy, are manufactured in India from rectified molasses spirit, distilled in patent-stills. For imitation whisky and brandy, the patent-still spirit is drawn at not below 166° proof. The spirit is diluted to the required strength and compounded with essences to imitate whisky and brandy. In certain localities, as in Punjab, the patent-still spirit is redistilled in pot-stills and the middle fraction diluted and flavoured with essences. Spirits prepared from gur base are also employed to produce whisky and brandy. The liquors are coloured with caramel. Only a few of the distillers subject the products to aging before bottling.

Genuine whisky is prepared from barley malt at Kasauli by *Dyer Meakin Breweries Ltd.* using pot-stills. Each batch is triple-distilled. The middle fraction of the final redistilled product is run into sherry casks and aged for a period of 2 to 8 years before issue. The product is reported to be inferior to Scotch and Irish whiskies. Indian barley, containing as it does a large percentage of nitrogenous constituents, is not so good a raw material for whisky manufacture as Scottish barley and climatic conditions in India are not favourable for the production of a high quality product.

Genuine brandy from grape juice is prepared in small quantities at the Khalsa distillery (Punjab) in pot-stills. The main difficulty is the lack of adequate supplies of suitable grapes. Grapes of the quality required are grown in Baluchistan and North West Frontier Province. Raisins may be used, but appropriate methods have to be developed for processing them.

The bulk of rum produced in India is genuine

DISTILLED LIQUORS

as it is distilled from fermented sugar cane products, such as molasses, gur, and cane juice. Patent-stills generally, and pot-stills occasionally, are used in its preparation. Fermented gur is distilled only in pot-stills and the rum obtained is of high quality. For preparing rum from patent-still spirit, redistillation is not necessary, but excise rules in Punjab demand that it should be redistilled. The patent-still spirit should be drawn at a strength not exceeding 130° proof as otherwise the bouquet will be lost.

Gin is produced at Rampur, Rosa, Karnal, and Khasa. High grade 'silent' (i.e. extra neutral) molasses spirit (not below 168°-169° proof), obtained by patent-still distillation and subsequent pasteurization to remove fusel oils and aldehydes, is redistilled after dilution to proof strength with juniper berries, coriander, and other flavouring agents in pot-stills fitted with gin heads.

Details relating to the flavouring materials employed in gin production are kept as trade secrets. It has been ascertained in one case that extra neutral alcohol of proof strength is redistilled with a botanical charge of juniper berries, coriander seeds, cardamom, and cinnamon. The crude gin so obtained is redistilled in a second pot-still to eliminate the terpenes and other undesirable constituents extracted from juniper berries. The middle runnings (c. 30° o.p.) are retained, and diluted to 65° proof prior to bottling. The mixture of foreshots and tailings is re-rectified for sale as industrial alcohol.

Imitation gin is produced from molasses or gur spirits by flavouring with gin essence.

Sugar is often added to whisky, brandy, and rum for obscuration of the true alcoholic strength.

Oak wood (from *Quercus dilata* and *Q. semicarpifolia*), dhama (*Grewia tiliacefolia* and *G. vestita*), and sandan (*Ougeinia dalbergioides*) are suitable for making liquor casks (Trotter, 1944, 207).

In Punjab, bottling is usually carried out in quart bottles (26.6 oz.), pint bottles (13.3 oz.) and nip bottles (6.6 oz.). In other States, quart bottles (24 oz. and 22 oz.) and pint bottles (12 oz. and 11 oz.) are used.

Production and Trade—Country spirits form the bulk of distilled liquors produced in India, with plain spirit as the predominant variety. Table 1 gives the production of distilled liquors in India.

Imports—Table 2 gives the annual imports of distilled liquors into India.

France was the principal supplier of brandy, her share in India's imports during the quinquennium ending 1938-39 being 95.1%; whisky, rum, and gin come mostly from U.K., her share in India's imports during the quinquennium ending 1938-39 being 99.6, 83.4, and 98%, respectively. Liqueurs were obtained from France and U.K., their share being 41.9 and 36.9%, respectively. The c.i.f. prices per gallon in 1938-39 were as follows: whisky, Rs. 16.0; brandy, Rs. 15.6; rum, Rs. 9.2; gin, Rs. 8.6; and liqueurs, Rs. 21.3.

Customs tariff, excise duties, and revenue from liquor—Potable spirits are subject to heavy excise and customs duties. There is no uniformity in the rates of duties levied in different States. Imports of potable spirits, such as brandy, gin, whisky, and other sorts of more than 42° proof spirit, are subject to a revenue duty of Rs. 95-10-0 per imperial L.P. (London Proof, defined as a mixture of alcohol and water "such as shall at a temperature of 51° F. weigh exactly 12/13 part of an

TABLE 1—PRODUCTION OF DISTILLED LIQUORS IN INDIA*
(Qty in thousand L.P. gal.)

| Country spirit | 1938-39 | 1942-43 | 1945-46 | 1946-47 | 1947-48 | 1950† | 1951† |
|--------------------|----------------|-----------------|-----------------|-----------------|-----------------|--------------|--------------|
| Plain | 5,911.7 | 3,296.6 | 11,058.4 | 11,175.0 | 8,833.4 | n.a. | n.a. |
| Spiced | 682.4 | 668.8 | 751.3 | 768.3 | 553.3 | n.a. | n.a. |
| Sophisticated | 60.8 | 451.8 | 170.1 | 175.1 | 143.7 | n.a. | n.a. |
| Total | 6,654.9 | 4,417.2 | 11,979.8 | 12,113.4 | 9,530.4 | 2,352 | 2,018 |
| Foreign spirit | | | | | | | |
| Whisky | 16.9 | 129.1 | 310.2 | 269.4 | 187.2 | n.a. | n.a. |
| Brandy | 24.7 | 161.7 | 233.9 | 298.7 | 277.9 | n.a. | n.a. |
| Rum | 60.0 | 262.7 | 574.8 | 447.5 | 261.9 | n.a. | n.a. |
| Gin | 10.6 | 132.8 | 330.7 | 95.4 | 80.3 | n.a. | n.a. |
| Other sorts | 5.2 | 44.4 | 68.9 | 33.3 | 35.8 | n.a. | n.a. |
| Total | 117.4 | 730.7 | 1,518.5 | 1,144.3 | 783.1 | 168 | 175 |
| Grand total | 6,772.3 | 10,147.9 | 13,498.3 | 13,262.7 | 10,313.5 | 2,520 | 2,193 |

* Monthly Statistics of the Production of Certain Selected Industries in India, D.G.C.I. & S.

† Information from the Development Wing, Ministry of Commerce & Industry

DYESTUFFS

TABLE 2—IMPORTS OF DISTILLED LIQUORS
(Qty in thousand gal. and value in lakh Rs.)

| | Whisky | | Brandy | | Rum | | Gin | | Liqueurs | | Total | |
|---------------|--------|------|--------|------|------|------|-------|------|----------|------|-------|-------|
| | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. |
| 1934/35- | | | | | | | | | | | | |
| 1938/39 (av.) | 323.4 | 54.8 | 112.6 | 17.5 | 2.1 | 0.2 | 87.6 | 7.8 | 12.1 | 2.6 | 537.8 | 82.9 |
| 1939/40- | | | | | | | | | | | | |
| 1943/44 (av.) | 300.2 | 57.4 | 80.7 | 13.8 | 2.1 | 0.3 | 95.8 | 13.3 | 4.5 | 1.0 | 483.3 | 85.8 |
| 1944-45 | 203.3 | 46.0 | 106.8 | 15.2 | 0.2 | 0.02 | 76.9 | 13.9 | 0.5 | 0.1 | 387.7 | 75.2 |
| 1945-46 | 234.5 | 54.2 | 209.4 | 46.3 | 0.04 | 0.01 | 138.8 | 23.5 | 1.2 | 0.3 | 583.9 | 124.3 |
| 1946-47 | 309.5 | 73.3 | 227.1 | 63.3 | 6.6 | 1.8 | 93.3 | 14.9 | 17.9 | 5.8 | 654.4 | 159.1 |
| 1947-48 | 232.6 | 56.4 | 96.1 | 31.4 | 2.5 | 0.6 | 35.1 | 6.9 | 11.4 | 3.6 | 377.7 | 98.9 |
| 1948-49 | 147.1 | 36.0 | 90.3 | 27.2 | 1.3 | 0.3 | 51.7 | 8.7 | 1.8 | 0.6 | 283.2 | 72.8 |
| 1949-50 | 142.3 | 32.9 | 47.8 | 13.1 | 1.5 | 0.3 | 19.7 | 3.4 | 2.6 | 0.9 | 213.9 | 50.6 |
| 1950-51 | 176.8 | 40.3 | 64.9 | 20.8 | 0.7 | 0.1 | 37.6 | 6.1 | 0.6 | 0.3 | 280.6 | 67.6 |
| 1951-52 | 171.9 | 49.2 | 66.5 | 23.2 | 1.4 | 0.2 | 35.6 | 7.0 | 6.6 | 2.6 | 282.0 | 82.2 |
| 1952-53 | 183.2 | 56.5 | 27.5 | 12.2 | 1.1 | 0.2 | 21.9 | 4.9 | 10.8 | 4.3 | 244.5 | 78.1 |

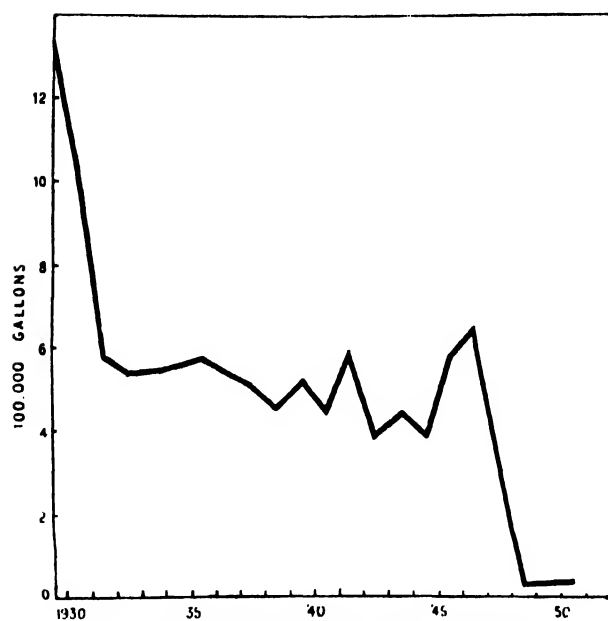


FIG. 23—IMPORTS OF DISTILLED LIQUORS

equal measure of distilled water also at 51°F.) gallon; the duty on rum is Rs. 55-5-0 per imperial L.P. gallon.

TABLE 3—PRICES OF COUNTRY SPIRITS IN PUNJAB
(per dozen bottles)

| | Quarts | | | Pints | | | Nips | | | |
|--------|--------|-----|----|-------|-----|----|------|-----|----|--------------|
| | Rs. | as. | p. | Rs. | as. | p. | Rs. | as. | p. | |
| Plain | 10 | 1 | 0 | 6 | 0 | 0 | 4 | 8 | 0 | without duty |
| do. | 44 | 1 | 0 | 23 | 0 | 0 | 13 | 0 | 0 | with duty |
| Spiced | 11 | 8 | 0 | 6 | 11 | 0 | 4 | 14 | 0 | without duty |
| do. | 47 | 5 | 0 | 24 | 11 | 0 | 13 | 14 | 0 | with duty |

Selling prices of plain and spiced spirits are controlled. The prices per bulk gallon are : plain, Rs. 1-9-4; and spiced, Rs. 2-2-6. Table 3 gives the prices per dozen bottles of plain and spiced spirits in Punjab during 1949-50. The prices of special spiced spirits and foreign spirits made in India vary according to quality and market demands.

DYESTUFFS

Dyes are employed for imparting colour to a wide variety of materials, but their major use is in the dyeing of textiles. Besides the textile industry, other colour-using industries are leather, paints and varnishes, printing and writing inks, paper, fur goods, foods and drugs, perfumes and cosmetics, and photographic films and plates. Dyes are used as stains in bacteriological and histological work and as indicators. The use of some dyes for non-colouring purposes is based on their incidental antibacterial and chemotherapeutic properties.

Natural dyes are of vegetable, animal, or mineral origin. With the advent of synthetic dyes, natural colouring matters have lost their commercial importance and at present they hardly account for even 1% of the dyestuffs used in the textile industry.

The discovery of the first synthetic coal tar dye, Mauve, by Perkin in 1856 was an event of outstanding scientific and industrial importance. It ushered an era of spectacular achievements in synthetic organic chemistry and heralded the rise of a new chemical industry. A large number of coal tar dyes were discovered soon after Perkin's first synthesis, and within two decades, synthetic dyes were being produced in England, France, Germany, and Switzerland. The German industry, in particular, made phenomenal progress and at the time World War I broke out, England and

America were importing a major part of their dyestuffs requirements from Germany. The vital importance of the industry, with its close association with organic chemicals, including explosives, synthetic drugs, and rubber chemicals, was recognized and vigorous measures were taken to consolidate and develop the industry. At the time World War II broke out, U.S.A. and U.K. had become important exporting countries; the industry in Japan, which had its beginning in 1914, was well established; Russia, France, Switzerland and Poland were also important producers of dyestuffs. Germany still retained its leading position, U.S.A. coming next and Russia, third. The curtailment of exports from Germany during World War II gave a further fillip to the industry in U.S.A. and U.K., and U.S.A. has now become the world's largest producer and exporter of coal tar dyes.

The number of commercial homogeneous dyes, pigments, etc. in current use is probably of the order of 5,000. They account for something like 25,000 commercial brands. The commercial name for a single dye entity may be one, if it is a speciality produced by one firm, or many, if it is produced by a number of different firms. An example of the latter is Direct Brown M which appeared in the first edition of the Colour Index as C.I. 420; at least 62 commercial names are now used for this dye by manufacturers (Information from the *Society of Dyers & Colourists*, London). Table 1 gives production and exports of synthetic dyes in the principal manufacturing countries in 1950-51.

NATURAL DYES

In spite of the extensive use of synthetic dyestuffs, a few natural dyes are still used for dyeing textiles and for colouring foods. Vegetable colouring matters are derived from woods, stem barks, fruits, and flowers of a large variety of plants. Cochineal, kermes, and lac dye, prepared from the dried bodies or exudates of certain

insects, are among the natural dyes of animal origin. Mineral colouring matters are represented mainly by the khaki dyeings on cotton obtained by the use of mixtures of iron and chromium salts. The more important natural dyes are mentioned below:

INDIGO—Before the advent of the synthetic product, India held the monopoly for natural indigo derived from *Indigofera* spp. The steep fall in exports since the beginning of this century and the decline of the Indian indigo industry will be clear from the following figures: 1882/83-1891/92 (av.), 141,811 cwt.; 1892/93-1901/02 (av.), 135,396 cwt.; 1909/10-1914/15 (av.), 15,000 cwt.; 1935/36-1939/40 (av.), 158 cwt. A small quantity of indigo is still produced in Madras and Bihar, particularly in Madras, for local consumption. Table 2 gives the exports of indigo in recent years.

Indigo occurs as the glycoside of indoxyl (indican) in the leaves of the indigo plant and is prepared by extracting the leaves either by the wet or the dry process. In the wet process, freshly cut plants are steeped in water in stone vats and macerated at 25-30° for 12 hr. or more when indican undergoes hydrolysis (due to the action of enzymes naturally present in the leaves) and indoxyl and glucose are formed. The liquid is drained into beating vats and indoxyl is oxidized by continuous mechanical beating to indigotin which settles down as a dark blue mud. The supernatant liquid is removed and indigo mud washed free from soluble matter. It is then boiled with water, filtered, pressed into blocks or cubes (c. 3 in. square), and finally dried. In the dry process, which is practised in Madras, bundles of freshly cut plants are dried and the leaves separated from the stems by beating. The colour of the leaves changes in a few weeks to pale blue-green. The leaves are then steeped in water, fermented and macerated for about 2 hr. The green liquor is drawn into beater vats and indigo is precipitated. The precipitate is washed, pressed

TABLE 1—PRODUCTION AND EXPORTS OF DYESTUFFS*

| | Production (metric tons) | | Exports | | | |
|-------------|-----------------------------|--------|----------------------|-------------|----------------------|-------------|
| | | | 1950 | | 1951 | |
| | 1950 | 1951 | Qty (metric tons) | Val. (£) | Qty (metric tons) | Val. (£) |
| Belgium | n.a. | n.a. | 1,014 | 1,070,770 | 1,299 | 1,143,800 |
| France | 15,000 | 13,939 | 4,696 | 4,101,400 | n.a. | n.a. |
| Germany | 29,849 | 31,730 | 12,742 | 14,536,00 | 16,310 | 19,970,700 |
| Italy | 8,587 | 8,833 | 1,006 | 944,300 | 1,080 | 1,182,300 |
| Switzerland | n.a. | n.a. | 9,844 | 18,112,000 | 8,916 | 17,806,800 |
| U.K. | n.a. | n.a. | 13,939 | 10,183,484 | 11,434 | 8,033,865 |
| U.S.A. | 110,263 | n.a. | 12,290 | 11,487,500 | 8,615 | 9,493,700 |

* Rep. Progr. appl. Chem., 1951, 36, 133

TABLE 2—EXPORTS OF INDIGO

| | Qty (cwt.) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1929/30-1933/34 (av.) | 689 | 1,71,046 |
| 1934/35-1938/39 (av.) | 428 | 72,656 |
| 1939-40 | 158 | 17,473 |
| 1940-41 | 30 | 7,672 |
| 1941-42 | 25 | 4,042 |
| 1942-43 | 71 | 30,775 |
| 1943-44 | .. | .. |
| 1944-45 | 6 | 6,336 |
| 1945-46 | 13 | 8,736 |
| 1946-47 | 1,004 | 6,84,123 |
| 1947-48 | 518 | 75,950 |
| 1948-49 | 588 | 59,197 |
| 1949-50 | 115 | 18,080 |
| 1950-51 | 4 | 3,252 |
| 1951-52 | 216 | 1,15,921 |
| 1952-53 | 271 | 84,611 |

into cakes, and dried in the usual way (Ghosh, *Sci. & Cult.*, 1943-44, 9, 487, 537).

SAFFLOWER CARMIN—Safflower dye is obtained from the florets of *Carthamus tinctorius*. The florets are collected and dried in shade. The dried material is repeatedly washed with acidulated water for 3-4 days till all the water-soluble, yellow colouring matter is eliminated. The residue is partially dried and moulded into cakes. In some places the dried florets, without any preliminary washing, are rolled together into fibrous masses or reduced to a loose powder for the market. Safflower Carmin of commerce is extracted from the washed material by sodium carbonate solution and precipitated by dilute acid. It is used for dyeing cotton and silk to impart red, pink, rose, crimson, or scarlet shades as required. The dyeings are fugitive to light and air, and sensitive to alkali, chlorine, and sulphurous acid. Safflower carmin is a weak dye, 1 lb. of yarn requiring nearly 4 oz. of the colouring matter to give a light pink shade, 8 oz. to give a rose-pink shade, and 1 lb. to produce full crimson shade. Though its importance as a dye for cotton and silk has declined, due to competition from synthetic dyestuffs, it is still valued in India for dyeing cloth required for ceremonial occasions. The dye also finds use in colouring cakes and biscuits. When present in appreciable concentrations in eatables, it acts as a cathartic. With starch and talc, it is used in the preparation of rouge. It is also used for colouring toys.

Safflower carmin was being exported from India before World War II to Straits Settlements, Hong Kong, Java, Japan and other countries in the east. Table 3 gives the exports of safflower carmin during the period 1929-42.

SAPPAN WOOD—The source of the colouring matter in sappan wood (*Caesalpinia sappan*) is brazilin, $C_{16}H_{14}O_5$, soluble in water and alcohol, and crystallizing in colourless silky needles. On exposure to atmospheric oxygen, brazilin is converted into brazilein, $C_{16}H_{12}O_5$. For extracting the colouring matter, the wood is cut into chips or rasped into powder and extracted with hot water. The deep orange extract is fermented to convert brazilin to brazilein before use. Sappan wood extract finds use in calico printing. Aluminium acetate or stannic oxalate is used as mordant in combination with an oxidizing agent (potassium chlorate or copper sulphate). With cotton fabrics mordanted by tannin-alum, sappan wood extract produces a bright reddish orange shade. Purple shades are obtained in combination with indigo. Wool and silk can be dyed using alum, potassium dichromate, or iron salts as mordants, but the shades produced are not fast (Shroff & Trivedi, *Bull. Dep. Industr. Comm., U.P.*, No. 7, 1940, 35).

CATECHU or **CUTCH**, obtained from *Acacia catechu*, is used in cotton and silk dyeing and in calico printing. Exports to Europe, which were once considerable, have dwindled in recent years due to replacement by cheaper materials, such as mangrove. Cutch is still in demand for dyeing fishing nets, awnings, sail-cloth, and mail bags. It is also used for dyeing wool and silk and for weighting the latter. It imparts brown shades (Catechu or Cutch Brown) to cotton in conjunction with copper sulphate and sodium dichromate. Catechu Brown was reputed at one time to be fast to light, acid, alkali, and bleaching powder. Although this is not true according to modern standards, it continues to be used in dyeing as it has also a preservative action. It is probably used to a larger extent in printing than in dyeing (Ramachandran & Venkataraman, *J. Soc. Dy. Col.*, 1938, 54, 513).

TABLE 3—EXPORTS OF SAFFLOWER CARMIN

| | Qty (cwt.) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1929/30-1933/34 (av.) | 2,321 | 56,478 |
| 1934/35-1938/39 (av.) | 2,666 | 46,639 |
| 1939-40 | 2,838 | 68,484 |
| 1940-41 | 2,499 | 79,710 |
| 1941-42 | 3,289 | 87,630 |
| 1946-47* | 830 | 74,272 |
| 1947-48 | 37 | 3,000 |
| 1948-49 | 541 | 28,023 |
| 1949-50 | 456 | 22,658 |
| 1950-51 | 65 | 4,685 |
| 1951-52 | 79 | 13,904 |
| 1952-53 | 46 | 13,953 |

* No exports during the preceding 4 years.

Catechu may be used in admixture with direct dyes, selected with regard to their resistance to the action of copper sulphate and potassium bichromate. Basic dyes may also be used on a catechu bottom, the latter acting as a mordant.

The use of cutch has been recently suggested for khaki dyeing. By coupling cutch with diazo salts a range of bright and attractive shades with moderate fastness can be produced (Indian Pat., 26980, 24056).

Cutch dyeings not only exhibit greater fastness to weather conditions than dyeings with coal tar dyes, but are also less liable to attack by mildew. The treatment of jute for rot-proofing with cutch and potassium dichromate has recently been patented. Cutch may also be used for colouring pulp and paper (Brit. Pat., 462306; Puntambekar & Batra, *Indian For. Leaf.*, No. 44, 1943).

MADDAR root was for long the most important commercial source of a red colouring matter (alizarin) used in the dyeing of cotton. It is now occasionally used as an addition to the fermentation indigo vat.

KAMALA dye (principal colouring principle, rottlerin) is an orange red powder obtained as a glandular pubescence on the exterior of the fruits of *Mallotus philippinensis*, which grows throughout the tropical hills of India. The ripe capsules are gathered and shaken in bags until the powder separates; alternatively, the fruits are stirred in water and the sediment collected in the form of cakes. About 1,000 md. of the powder are annually collected in Uttar Pradesh alone. Kamala was formerly used in India for dyeing silk and wool to a bright orange colour; it is still used for this purpose to a limited extent and for colouring oils, soaps, ice-creams, and drinks. Rottlerin and its tri- and penta-potassium derivatives are employed for colouring lemonades, lime juice, and other beverages (Lal & Mukherjee, (*Bull. Dep. Industr. Comm., U.P., New Series*, No. 12).

ANNATTO dye is obtained from the seeds of *Bixa orellana*. The scarlet arils surrounding the pod yield a bright yellow dye used for colouring wool, silk, and calico; it is also used for colouring butter and other foodstuffs. For extracting the dye, the seeds are bruised and the pulp macerated with hot water in wooden vessels and soaked for several days. The seed residue is removed and the brei containing the pigment is fermented for about a week. The dye which settles at the bottom is separated and dried into cakes (yield, 4.8-6% by wt. of seeds). Alternatively, crushed seeds are extracted with boiling sodium carbonate solution and the extract acidified. The colouring matter is coagulated by adding common salt and

boiling. The coagulum is filter-pressed, washed, and dried (*J. sci. industr. Res.*, 1942, 1, 65).

Annatto is marketed in the form of cakes, tablets, or paste. The principal colouring matter of the seeds is bixin, $C_{23}H_{30}O_4$, which is present to the extent of 10-12%.

TURMERIC obtained from the rhizomes of *Curcuma longa* is used in dyeing wool, silk, and unmordanted cotton to which it imparts a yellow shade in an acid bath. In spite of its poor light-fastness it is still employed in cotton dyeing, sometimes in combination with other natural dyes, like indigo and safflower, to impart different shades. It is used alone for dyeing cotton fabrics in Indian homes for use on ceremonial occasions. It is also used as a colouring matter in pharmacy and food industry. Turmeric paper is an official reagent in the British Pharmacopoeia for testing alkalinity. A dilute tincture of turmeric is suitable for use as a fluorescence indicator even in brown and yellow solutions (*Chem. Abstr.*, 1938, 32, 6579).

LOGWOOD—The only vegetable colouring matter which still retains appreciable commercial importance is logwood (from *Haematoxylon campechianum*). It is a true mordant dye employed in dyeing Logwood Blacks on wool and silk, and to a limited extent on cotton and linen. The red colouring matter, haematein, occurs in logwood as the colourless dihydro derivative, haematoxylin. Haematoxylin is used also as a stain in histological work.

SAFFRON—A yellow, water-soluble dye is obtained from saffron (*Crocus sativus*); it is used for colouring butter, cheese, puddings, pastry, and confections to which it imparts also a characteristic flavour.

CHLOROPHYLL—The use of chlorophyll as a colouring matter has of late assumed importance. It is manufactured on a commercial scale in U.S.A. and is a by-product of the alfalfa dehydration industry. Chlorophyll extract is used for colouring soaps, oils, perfumes, confectionery, liquors, and toilet preparations. It forms the base for water-soluble copper chlorophyll, widely employed in deodorant tablets, breath candies, mouth washes, tooth pastes, chewing gums, face creams, and ointments.

The Indian stinging nettle, *palak*, and *bhant* have been employed as rich sources of chlorophyll by workers at the Forest Research Institute, Dehra Dun. Copper chlorophyll of high tinctorial value (120-140%) is obtained in a yield of 60-70 g. per kg. of dry *palak* leaves.

CAROTENE—The yellow colouring matter from carrot, carotene, is used for colouring and fortifying butter and cheese.

LITMUS, a purple dye, is extracted from some

TABLE 4—IMPORTS OF COCHINEAL

| | Qty (cwt.) | Val. (Rs.) |
|---------|---------------|---------------|
| 1939-40 | 1,186 | 2,42,136 |
| 1940-41 | 366 | 65,804 |
| 1941-42 | 385 | 70,103 |
| 1942-43 | 1 | 877 |
| 1943-44 | 2 | 537 |
| 1944-45 | 1 | 424 |
| 1945-46 | 8,066 | 82,868 |
| 1946-47 | 4,883 | 8,49,901 |
| 1947-48 | 67 | 44,024 |
| 1948-49 | 63 | 36,700 |
| 1949-50 | 4 | 2,626 |
| 1950-51 | 22 | 16,761 |
| 1951-52 | 526 | 4,01,291 |
| 1952-53 | 141 | 91,387 |

species of lichens. Litmus is used as an indicator for acids and alkalis.

COCHINEAL—The scarlet dye obtained from the dried bodies of the Mexican insect, *Coccus cacti*, was extensively employed for obtaining scarlet shades on wool and silk. It is still used to a limited extent in dyeing Ludhiana and Kashmiri shawls. In Kollegal and Mysore, it is used for dyeing silk fabrics to obtain permanent shades of deep crimson and red. Silk is preferably first dyed yellow, mordanted with nitromuriate of tin, and finally dyed in a second bath with the assistance of cream of tartar. Silk can also be dyed in a single bath with cochineal, stannous chloride, and oxalic acid (Ayyar, *Agric. Live-stk India*, 1931, 1, 229; Phadke, 39, 44; Perkin & Everest, 90).

Cochineal is commonly used as a colouring matter for drugs and confectionery, and in the preparation of rouge and other cosmetics. It is used also as a stain in the laboratory (Redgrove,

115, 121). Table 4 gives the imports of cochineal into India.

LAC dye obtained from the exudation of the insect, *Laccifera lacca*, has been known and used as a colouring material since ancient times. The export of lac dye from India in 1869-70 was c. 21,000 cwt. valued at Rs. 9½ lakhs. The dye is now only of historic interest.

SYNTHETIC DYES

Classification—Synthetic dyes may be classified either according to their chemical composition or their application. There is, to some extent, common ground between the two classifications; for example, the methods of applying sulphur colours take into account the chemical character of the dyes. Also, the dyeing properties are useful for subdividing groups, such as azo or anthraquinone dyes, which contain a large number of individual dyestuffs; thus it is convenient to divide anthraquinone dyes into cellulose acetate, mordant, acid, and vat dyes. Table 5 gives the classification of dyes based on the combined consideration of constitution, preparation, and application (Venkataraman, 1, 241).

From the sale and utilization points of view, dyes are classified according to their application. All dyes used for dyeing wool and silk from an acidic bath are called Acid Dyes; those used in dyeing cotton directly are Direct or Substantive Dyes, and so on. According to this classification dyes are grouped as Acid Dyes, Azoic Dyes, Basic Dyes, Direct, Substantive or Salt Dyes, Dyes for Acetate Rayon, Oxidation Dyes, Mordant or Chrome Dyes, Sulphur or Sulphide Dyes, and Vat Dyes. Table 6 gives the classification of dyes according to their dyeing properties.

TABLE 5—CHEMICAL CLASSIFICATION OF DYES

| Class name | Characteristic unit and special preparation features | Example | Remarks |
|--------------|---|-------------------|---|
| Nitro dyes | Phenols or amines containing nitro groups in the o- and/or p-position | Naphthol Yellow S | Water soluble members are acid dyes for dyeing wool and silk; insoluble compounds useful as pigments |
| Nitroso dyes | Phenols and naphthols containing nitroso group in the o- and p-position | Fast Green O | Small and technically unimportant group. p-Nitroso-phenol is an intermediate for indophenols. o-Nitrosophenols form metal complexes having mordant dyeing properties and yield differently coloured complexes with heavy metal oxides. Green iron lakes are used in limited quantity in dyeing and printing |

TABLE 5—Contd.

| Class name | Characteristic unit and special preparation features | Example | Remarks |
|--|--|-------------------------------------|---|
| Azo dyes | (-N=N-)X Prepared by diazotising aromatic amine and coupling the resulting diazonium salt with a phenol or aromatic amine having a free <i>o</i> - and/or <i>p</i> - position, or certain other components containing reactive groups, such as β -ketonic acid arylamides | | Numerically the most important group consisting of 50-75% of all synthetic dyes in use |
| (1) Monoazo dyes | Ar-N=N-Ar' | Orange II | Yellow to blue dyes for wool and a few basic dyes for cotton |
| (2) Disazo dyes | Ar-N=N-Ar'-N=N-Ar'' | Congo Red | Large variety of soluble dyes for cotton and wool and a limited range for leather |
| (3) Trisazo and Tetrakisazo dyes | Ar-N=N-Ar'-N=N-Ar''-N=N- | Direct Green B | Essentially direct cotton dyes and a few useful leather dyes |
| (4) Urea and cyanuric acid derivatives | Mainly di- and tri-azo dyes in which azo dye units are linked together by means of urea or thiazine | Sirius Supra Yellow | Direct cotton dyes |
| (5) Mordant dyes | Hydroxyazo group | Eriochrome Black T | Wool dyes of various shades |
| (6) Pyrazolone dyes | 1-Phenyl-4-benzene-azo-5-pyrazolone | Tetrazine | Yellow to red acid dyes |
| (7) Stilbene dyes | Stilbene and azo or azoxy groups | Constituent of Diphenyl Citronine G | Yellow, orange, and brown direct cotton dyes |
| (8) Cellulose acetate dyes | Mainly monoazo dyes containing β -hydroxyethyl and similar groups | Celliton Discharge Scarlet B | Used in the form of aqueous dispersion; suitable for application to acetate rayon; full range of shades |
| (9) Azoic dyes | Coupling of mainly nitro-, chloro-, and alkoxy-anilines and toluidines with aryl amides of naphthoic acid or acetoacetic derivative | Scarlet GG | Insoluble dyes prepared on the fibre or in substance for use as pigments |
| Thiazoles | Aminothiazole- or azothiazole-sulphonic acid; or thiazolium salt | Primuline | Very limited in number; direct cotton, sulphurized vat, and cyanine dyes |
| Diphenylmethanes | Dimethyl aminodiphenyl-methane derivatives | Auramine O | A basic yellow dye of poor fastness; extensively used because of cheapness and brilliant shades for dyeing and printing cotton, paper, silk, leather, jute, and wool |
| Triphenyl-methanes | Derivatives of triphenyl-methane or triphenylcarbinol having one or more primary, secondary, or tertiary amino groups <i>para</i> to the methane carbon atom | | Basic, acid, mordant, and lakes according to the auxiliary groupings they contain; and characterized by brilliant and intense shades of red, violet, blue, and green; used extensively for dyeing and printing cotton, and dyeing wool. Pigments are obtained by precipitating basic triphenyl-methane dyes with complex acids, such as phosphomolybdic and phosphotungstic acids |

DYESTUFFS

TABLE 3—Contd.

| Class Name | Characteristic unit and special preparation features | Example | Remarks |
|-----------------------------------|---|---|--|
| (1) Malachite Green | Contain 2 amino groups | Malachite Green | Acid, basic, and mordant dyes of green and blue shades; some are powerful bactericides; also used as bacteriological and histological stains |
| (2) Rosaniline series | Contain 3 amino groups | Rosaniline, Magenta, Methyl Violet | Acid and basic dyes of red, violet, yellow, and sometimes blue and green shades; also used in inks, copying pencils, typewriter ribbons, and other coloured materials |
| (3) Rosolic acid series | Contain 3 hydroxyl groups; important dyes are salicylic acid derivatives | Aurine, Chrome Violet | Valuable mordant dyes used for calico printing and dyeing |
| (4) Phthaleins | Prepared by treating phenol with phthalic anhydride in presence of zinc chloride; OH groups in <i>para</i> position | Phenolphthalein | Used as an indicator |
| Xanthenes | Xanthene or dibenzo- γ -pyran derivatives; closely related to the triphenylmethane class, from which these differ by the presence of an oxygen atom linking two of the benzene nuclei | | Consists of basic, acidic, and a few mordant-fixing dyes comprising some of the most brilliant dyestuffs |
| (1) Diphenyl-methane derivatives | Prepared by condensing <i>m</i> -dialkylaminophenols with formaldehyde or succinic acid | Pyronine G, Rhodamine S | Pyramine G is a red basic dye. Rhodamine S has a limited use for pink shades on tannin-mordanted cotton and for colouring paper and wood |
| (2) Triphenyl-methane derivatives | 9-Phenyl xanthene derivatives. Obtained by condensing <i>m</i> -dialkylaminophenols with <i>ortho</i> substituted benzaldehyde derivatives | Rhodamine 5G | Acid and basic dyes |
| (i) Phthaleins | Prepared by heating phenol, cresol, or resorcinol with phthalic anhydride; phenol condenses in <i>ortho</i> position forming phenylxanthene derivatives; the parent substance of this group is fluorane | Fluorescein, Eosine, Gallein | Fluorescein is a red dye with green fluorescence used in the detection of flow of water, and its sodium and potassium salts in dyeing wool and silk in brilliant yellow shades. Eosine is a red dye with yellow fluorescence used mainly for colouring inks and dyeing paper and cosmetics. Gallein is a mordant dye |
| (ii) Rhodamines | Alkylamine derivatives of fluorane | Rhodamine B | Used for dyeing and printing cotton and for dyeing wool and silk; also as pigments |
| Acridines | Contain amino groups in 3, 6 positions and are salts of 9-hydroxy-9, 10-dihydro-acridine | Acridine Orange NO | Yellow, orange, and brown basic dyes with limited use in dyeing wool, silk, and jute; in calico printing and leather dyes; also used as antiseptics and medicinals |
| Azines | Contain dihydrophenazine derivatives | Mauvine, Safranine T, Indulines, Nigrosine, Aniline Black | Contain both basic and acidic dyestuffs ranging in shade from red to blue |

TABLE 3—Contd.

| Class Name | Characteristic unit and special preparation features | Example | Remarks |
|----------------------------|--|-------------------|--|
| Oxazines | Contain phenoxazine derivatives | Meldola's Blue | Basic, chrome-mordant, and direct cotton colours. The chrome-mordant dyes (Gallocyanine class) are valuable for both cotton and wool; light-fast direct cotton dyes are much more important than the basic oxazines; shades mainly blue |
| Thiazines | Contain phenothiazine derivatives | Methylene Blue | Basic, acid, and mordant dyes. Methylene Blue, a basic dye and the most important member of this group is used for dyeing and printing mordanted cotton, as an oxidation-reduction indicator, bacteriological stain, and as an antiseptic. Acid dyes obtained by using amines containing sulphonic group; dye mordanted wool to reddish blue shades; also used for calico printing |
| Anthraquinone dyes | Anthraquinone and Anthrone derivatives | | A large number of important dyes |
| (1) Cellulose acetate dyes | Aminoanthraquinone | Duranol Blue B | Used for cellulose acetate rayon and nylon; have good affinity, level-dyeing power, and excellent fastness. Sulphuric ester type (Solacet dyes) are water soluble and applied by direct dyeing method for dyeing wool, nylon, and cellulose acetate rayon |
| (2) Mordant dyes | 1, 2-Dihydroxyanthraquinone | Alizarin | Alizarin and alizarin derivatives are important mordant dyes of this group. Alizarin gives different shades with different mordants. Turkey Red is used for calico printing and dyeing cotton yarn. Alizarin lakes are sometimes used in paints and printing inks |
| (3) Acid dyes | Sulphonic acid of hydroxy- or amino-anthraquinone derivatives | Alizarin Irisol R | Acid and acid-mordant dyes. With the exception of azo dyes the most important dyes of wool and silk belong to this class. Anthraquinone acid dyes leave cellulose fibres unaffected and are therefore useful for cross dyeing union materials of cellulose fibres and wool or silk. The predominant shades are blue and green with excellent fastness to light |
| (4) Vat dyes | With the exception of pyrimidanthrone, all anthraquinone vat dyes contain 2 carbonyl groups as a 1, 4 quinone or as a part of complex quinone system in a polycyclic aromatic compound | | |

DYESTUFFS

TABLE 5— *Contd.*

| Class name | Characteristic unit and special preparation features | Example | Remarks |
|--|---|--------------------------------------|---|
| (i) Anthraquinone derivatives | Substituted anthraquinone | Indanthrene Blue RSN | |
| (ii) Anthrone derivatives | Benzanthrone, pyrimidanthrone, etc. | Caledon Jade Green | |
| Indigoid and thioindigoid dyes | The colouring matter contains the chromophoric chain $\text{-CO-C}\equiv\text{C-CO-}$ derived from indole or thionaphthene. Two units are linked to form a dye molecule | | Indigo and indigoid dyes are vat colours applicable to both cellulose and protein fibres. Thioindigoids constitute a much more important series than the indigoids used widely in wool dyeing and calico printing with extensive range of shades. The thioindigoids have a greater range of shades than the indigoids. The latter give pale yellow or pale brown vats in contrast to deep colours of the anthraquinone vat. The indigoids are inferior to anthraquinone vats regarding fastness on cotton |
| (1) 2, 2'-derivatives of indole and thionaphthene | | Indigotin, Ciba Violet A, Thioindigo | |
| (2) 2, 3'-derivatives of indole and thionaphthene | | Indirubin, Thioindigo Scarlet R | |
| (3) Condensation products of indoxyl, thioindoxyl, or isatin with suitable component | | Ciba Scarlet G | |
| Solubilized vat dyes | | | |
| (1) Indigoids | Sulphuric ester of leucoindigo; prepared by sulphonating dry leucoindigo with chlorosulphonic acid in pyridine (Bader & Sunder method) | Indigosol O | Indigosols are mainly indigoids and thioindigoids; used for dyeing cotton, wool, and silk; applied to wool as an acid dye and to cotton as a direct dye; calico printing |
| (2) Anthraquinoids | Sulphonic ester of leuco compounds of anthraquinoid vat dyes; prepared by treating a vat dye with fuming sulphuric acid (or an alkyl ester of chlorosulphonic acid), a metal (Cu, Zn, Fe) and pyridine; a metal complex of the pyridine salt of leuco derivative is formed which by treatment with caustic soda forms the soluble sodium salt | Soledon Blue 2RC | Most of the soledons are derived from anthraquinone vat dyes; used for dyeing cotton, wool, and silk |
| Sulphur dyes | High molecular compounds of indefinite structure, but probably containing sulphur | Sulphur Black T | Extensively used for dyeing unmordanted cotton; characterized by high order of fastness |

TABLE 5—Contd.

| Class Name | Characteristic unit and special preparation features | Example | Remarks |
|----------------------|---|---|--|
| Sulphur dyes —contd. | heterocycles and disulphide or sulfoxide groups. The group name covers the dyes which dissolve in aqueous sodium sulphide forming reduction products with a marked affinity for cotton and regenerated by air oxidation; prepared by thionation or heating with sulphur, sodium sulphide or polysulphide | | except to chlorine. Various shades of sulphur dyes, e.g. black, blue, brown, green, maroon, yellow, olive, tan, orange, are marketed, the black dye being the most important |
| Sulphurized vat dyes | Sulphur containing dyes, intermediate between vat dyes and sulphur dyes, of complex, but more definite constitutions than sulphur dyes. Insoluble in aqueous sodium sulphide but soluble in alkali sodium sulphide. Three types of dyes may be distinguished: (a) sulphurized indophenol derivatives, (b) sulphurized anthracene derivatives, and (c) sulphurized diaryl-aminobenzene derivatives | Hydron Blue, Indanthrene Olive 3G, Helindone Brown CV | Fast cotton and wool dyes; the fastness is inferior to vat dyes and superior to sulphur dyes |
| Phthalocyanines | Ring system of isoindole units and nitrogen atoms; prepared by combination of <i>o</i> -cyanobenzamide and phthalonitrile. It combines with various metals (Cu, Fe, Zn, Co, Pt, etc.) to form coloured compounds | Monastral Fast Blue BS | Pigments characterized by the brilliance and beauty of shades, high tinctorial power, and excellent fastness to light, heat, acid, and alkali; widely used for colouring paints, lacquers, printing inks, plastics, rubber, leather, cloth, and other materials for which blues and greens of high fastness are desired; can be used for printing calico and rayon |
| Cyanine dyes | Heterocyclic rings built up of two nitrogen-containing ring systems in one of which the nitrogen atom is tervalent and in the other it is tetravalent; the two nitrogen atoms are linked by a conjugated chain of an uneven number of carbon atoms | Kryptocyanine, Astraphloxine FF | Photographic sensitizers used extensively in colour photography; of limited interest for textiles |

TABLE 6—CLASSIFICATION OF DYES ACCORDING TO DYEING PROPERTIES

| Class Name | Dyeing properties | Chemical characteristics | Remarks |
|------------|--|---|---|
| Acid dyes | Dye wool and silk from an acid bath; have little or no affinity for cotton | Sodium salts of sulphonic acids of compounds belonging to nitrophenol, azo, triphenylmethane, anthraquinone, indigoid, and other series | Most important group of dyes for wool and protein fibres; water soluble |

DYESTUFFS

TABLE 6—Contd.

| Class Name | Dyeing properties | Chemical characteristics | Remarks |
|--------------------|---|---|--|
| Basic dyes | Dye wool from a neutral or weakly acidic bath, and cotton mordanted with tannic acid and tartar emetic or certain synthetic organic mordants | Basic dyes of different chemical classes may be obtained by the introduction of amino or dialkyl-amino groups and conversion into ammonium, sulphonium, or oxonium salts. The basic nitrogen is in the form of primary or tertiary amino group or a heterocyclic system | Yield intense brilliant shades but fugitive to light; water soluble |
| Direct cotton dyes | Dye cotton directly; also known as Salt Dyes since common salt is added generally for exhaustion; some dyes have no affinity for cellulose in the absence of inorganic electrolytes | Sodium salts of sulphonic acids of mainly azo dyes | Poor fastness to washing and light; can be improved by various after treatments on the fibre; water soluble; mainly used in cotton dyeing and printing and in the dyeing of viscose silk |
| Azoic dyes | Insoluble azo dyes prepared on the fibre, specially cotton & other cellulose fibres, by impregnation with an alkaline component followed by development with diazonium salt | β -Naphthol was used originally as a coupling component; now mainly arylamides of 2-hydroxy-3-naphthoic acid are used | Dyeing and printing cotton in fast shades |
| Mordant dyes | Metallic hydroxides and salts form complexes, called lakes; various metals, such as Al, Cr, Fe, and Sn are employed depending on the fibre and the chemical class of dye | Contain groups capable of holding metals in stable combination or chelate groups | No affinity for unmordanted fibre; Alizarin is the true example |
| Acid-mordant dyes | Acid dyes applied in conjunction with metallic mordants, particularly chromium compounds, to improve their fixation on the fibre | Mordant dyes sulphonated and rendered water soluble | Generally used for dyeing wool; commonly known as chrome colours |
| Vat dyes | Insoluble in water; solubilized by treatment with caustic soda and a reducing agent, usually hyposulphite; the resulting leuco compounds have affinity for textile fibre; on exposure to air the leuco compound on impregnated fibre reoxidizes to the insoluble parent dye; dyed from an alkaline bath | Mainly belong to indigo and anthraquinoid class | Characterized by high fastness, specially anthraquinoids; most valuable for dyeing and printing cotton; for dyeing wool and silk pH is kept below a point at which damage to protein fibre may occur; insoluble in water; with a deficiency in alkali the penetration is poor and fastness to rubbing inferior; with excess of alkali shades are apt to be uneven, and wool fibre damaged; also used for colouring nylon, cellulose acetate, paper, cement, plastics, etc.; specially made pigments of vat dyes are used in colouring paints, lacquers, varnishes, enamels, and like materials |

TABLE 6—Contd.

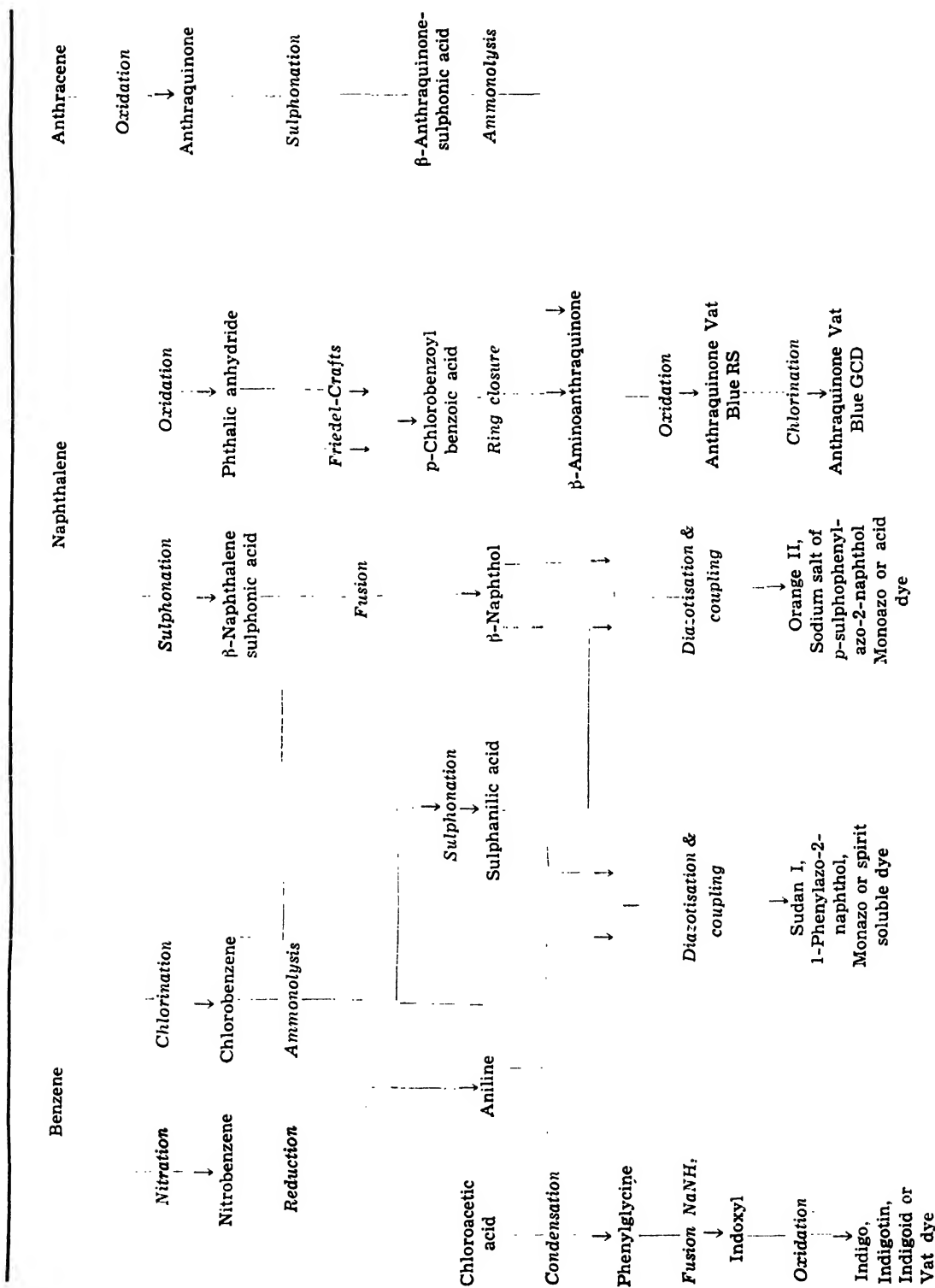
| Class Name | Dyeing properties | Chemical characteristics | Remarks |
|------------------------|--|--|---|
| Solubilized vat dyes | Water soluble stable derivatives of vat dyes; impregnated fibre when treated with an oxidizing agent, usually sulphuric acid and sodium nitrite for cotton, and sulphuric acid and dichromate for wool and silk, regenerates the parent vat dye by hydrolysis and oxidation; since no alkali is involved, this class of dyes is equally applicable to cellulose and protein fibres | Sodium salts of sulphononic esters of leuco compounds of indigoid and anthraquinoid vat dyes | Dyeing and printing cotton and wool in fast shades; indigosols were originally developed for use on wool and silk so that caustic soda required for vatting may be avoided; at present, however, indigosols and soledons are more important cotton dyes, because cheaper and better acid-mordant dyes are available for animal fibre; solubilized anthraquinone vat dyes are usually more substantive than indigoid derivatives |
| Sulphur dyes | Insoluble dye solubilized, as in the case of vat dyes, to sodium salt on reduction under alkaline conditions; sodium sulphide is employed for both purposes; dyeing is carried out from a hot sodium sulphide bath, and the parent dye regenerated by exposure to air | Prepared by heating certain intermediates with sulphur or sodium sulphide or sodium polysulphide; of unknown constitution | For dyeing cotton, as wool is damaged by sodium sulphide; sulphur black belongs to this group; insoluble in water |
| Oxidation colours | Colour produced on the impregnated fibre by oxidation | Aniline Black, only important dye of this class, is produced by treating the fibre with aniline hydrochloride and oxidizing it with sodium chlorate along with an oxygen carrier such as copper sulphate; other oxidation colours are produced by oxidizing <i>p</i> -phenylenediamine, <i>o</i> - and <i>p</i> -aminophenol, etc. on hair and fur | Aniline Black for dyeing and printing cotton; amines for dyeing fur; fast dyes |
| Cellulose acetate dyes | Aqueous dispersions of coloured compounds are used for dyeing cellulose acetate rayon | Amino-azo compounds and amino-anthraquinone derivatives, usually containing ethanolamine and similar groups which make them readily dispersible in water; some water soluble sodium salts of sulphononic esters of ethanol amine derivatives (Ar. NHCH ₂ CH ₂ OSO ₃ Na) are recently being used | Insoluble or sparingly soluble in water |

Table 7 gives the quantities of different types of dyes produced in U.S.A. in 1948.

Manufacture—The primary raw materials required for the manufacture of synthetic dyes are benzene, toluene, xylene, naphthalene, anthracene, and carbazole; other aromatic crudes employed are cresols, acenaphthene, and pyrene. They are obtained from coal tar and light oil

recovered from by-product coke ovens. Toluene, xylene, and other aromatic hydrocarbons are being manufactured in U.S.A. in increasingly large quantities from natural gas and petroleum by hydroforming or other aromatization processes.

The primaries are converted into dyes via intermediate products prepared through the introduction of sulphononic, hydroxyl, amino,



Sequence of dye manufacture from coal tar hydrocarbons

TABLE 7—PRODUCTION OF COAL-TAR DYES IN U.S.A. (1948)*

| | Qty (1,000 lb.) |
|--|--------------------|
| Azo | 88,559 |
| Sulphur | 20,366 |
| Indigoid and thioindigoid | 31,374 |
| Anthraquinone vat | 27,691 |
| Triphenyl methane and diphenyl naphthyl methane | 8,136 |
| Anthraquinone | 4,963 |
| Stilbene | 2,070 |
| Pyrozolone | 1,923 |
| Xanthene | 1,583 |
| Ketanimine | 1,266 |
| Thiazole | 1,255 |
| Thiazine | 79 |
| Acridine | 156 |
| Quinoline | 201 |
| Oxazine | 49 |
| Others | 3,243 |
| Total | 201,376 |

* Kirk & Othmer, V, 344

TABLE 8—PRODUCTION OF DYESTUFF INTERMEDIATES
IN U.S.A. (1948)*

| | Qty (1,000 lb.) |
|---------------------------------------|--------------------|
| p-Acetotoluide | 1,122 |
| 2-Aminoanthraquinone & salt | 1,225 |
| Amino I acid | 2,335 |
| Amino G acid | 1,524 |
| Tobias acid | 3,727 |
| H acid | 6,185 |
| 1, 2, 4-Acid | 1,529 |
| J acid | 1,345 |
| Gamma acid | 1,536 |
| Aniline | 92,083 |
| 1-Anthraquinone sulphonie acid & salt | 1,673 |
| Benzaldehyde, tech. | 1,500 |
| Benzanthrone | 1,158 |
| Benzidine hydrochloride and sulphate | 3,658 |
| o-Benzoylbenzoic acid | 4,038 |
| Chlorobenzene, mono | 303,056 |
| Dinitro chlorobenzene | 8,092 |
| Benzylchloride | 7,812 |
| o-Dichlorobenzene | 14,508 |
| Nitro-p-dichlorobenzene | 1,260 |
| N, N-Dimethyl aniline | 7,812 |
| N-Ethylaniline, refined | 1,051 |
| N,N-Ethylbenzyl aniline | 1,322 |
| 3-Hydroxy-2-naphthionic acid | 2,768 |
| p-Naphthionic acid | 2,778 |
| α -Naphthol | 758 |
| R acid | 1,072 |
| G acid salt | 1,246 |
| α -Naphthylamine | 5,737 |
| Nitrobenzene | 123,764 |
| Nitrotoluenes, mixed | 22,522 |
| 5-Nitro-o-toluenesulphonic acid | 2,191 |
| 2-Nitro-p-toluidine | 1,980 |
| Phenol, synthetic | 274,274 |
| Phenylenediamine | 2,688 |
| Phthalic anhydride | 158,827 |
| Sulphanilic acid and salt | 3,344 |
| 2, 4-Toluenediamine | 1,349 |

* Kirk & Othmer, V. 343

alkoxyl, or other groups into the parent hydrocarbon. Thus, α - and β -sulphonic acids are prepared from naphthalene by the action of sulphonic acid, which upon fusion with caustic soda give α - and β -naphthols; by heating β -naphthol with ammonia and sodium sulphite under pressure β -naphthylamine is obtained. Anthraquinone, an important intermediate for fast dyestuffs, is obtained by oxidizing anthracene. Benzaldehyde is produced from toluene and phthalic anhydride is produced from naphthalene. Methyl- and ethyl-anilines are obtained by heating aniline with methyl or ethyl alcohol and an acid under pressure. By introducing two or more groups, of the same or of different kinds, into the hydrocarbon nucleus, a great variety of intermediate compounds are obtained—diamines, dihydroxy compounds, amino-phenols, naphthol sulphonic acids, naphthylamine sulphonic acids, amido naphthols, etc. Isomerism plays an important role in these compounds, since the positions occupied by the groups is a factor of importance in determining the properties of the colouring matters. The commercial importance of some of the intermediates is illustrated by the production figures in U.S.A. during 1948 (Table 8).

The processes involved in the production of a dye from coal tar hydrocarbons are indicated in the flow diagram (p. 76).

The manufacture of intermediates presents more difficulties than the production of dyes themselves in view of the large variety of intermediate products and chemical reactions involved and the large size of the operations for producing them on an economic basis. It is obvious, however, that on account of the national importance of the dyestuff industry, production must be based on cheap and adequate supply of domestic raw materials.

THE INDIAN INDUSTRY

The need for the establishment of a national dyestuffs industry was keenly felt during the early part of World War II when the import of dyes practically ceased and the textile industry was faced with a dye famine. The Council of Scientific & Industrial Research appointed, in 1940, a Dyestuffs Exploratory Committee to survey the raw material resources and to make recommendations for the establishment of a dyestuffs industry in the country. The Committee recommended a 15-year plan for the manufacture of 51 dyes, (representing 50% of the total dyestuffs consumed and comprising 13 vat dyes, 1 sulphurized vat colour, 3 solubilized vat colours, 4 naphthols, 8 bases and salts, 9 direct colours, 7 basic colours, 3 acid colours, 2 sulphur dyes, and 1 mordant colour) involving the following stages: (1) manufacture of the 51 dyes within a period of 5 years after a brief period of preparation;

DYESTUFFS

TABLE 9—REQUIREMENTS AND AVAILABILITY OF COAL TAR RAW MATERIALS*

| | Requirements | Availability |
|--------------------------|--------------|--------------|
| Benzene, pure (gal.) | 400,000 | 2,417,000† |
| Toluene (gal.) | 125,000 | 374,000 |
| Naphthalene, pure (tons) | 1,000 | 1,100 |
| Anthracene, pure (tons) | 500 | 120 |
| Pyridine (gal.) | 2,000 | 225 |
| Carbazole (tons) | 15 | nil |
| Solvent naphtha (gal.) | 4,000 | 288,500 |

* Council sci. industr. Res. India, *Rep. Dyestuffs explor. Comm. (Appendices)*, 1946, 8

† Benzole 90's

TABLE 10—REQUIREMENTS AND AVAILABILITY OF ALIPHATIC RAW MATERIALS*

| | Requirements (tons) | Availability (tons) |
|----------------------|---------------------|---------------------|
| Alcohol, ordinary | 125 | 28,500 |
| Alcohol, absolute | 36 | |
| Methyl alcohol | 286 | 420 |
| Acetic acid, 40% | 50 | .. |
| Acetic acid, glacial | 100 | .. |
| Acetic anhydride | 150 | nil |
| Formaldehyde, 40% | 20 | 85 |
| Glycerine | 125 | 1,850 |
| Ethyl chloride | 30 | .. |
| Turkey Red Oil | 5 | (a) |

* Council sci. industr. Res. India, *Rep. Dyestuffs explor. Comm. (Appendices)*, 1946, 8

(a) quantity not known

TABLE 11—AVAILABILITY OF INORGANIC CHEMICALS

| | |
|---|--|
| Manufactured | Soda ash, bromine, common salt, sodium dichromate, potassium chloride and nitrate, caustic soda, chlorine |
| Manufactured (in insufficient quantities) | Oleum; sodium nitrate, sulphide, sulphite, bisulphite, thiosulphate, and hydrosulphate; aluminium chloride |
| Imported | Zinc, phosphorus compounds, potassium cyanide, selenium, iodine, sulphur |

(2) manufacture of some of the intermediates during the first 5-year period; (3) production of all the intermediates required for the 51 dyes within 10 years; and (4) production of all the dyes which are in substantial demand in the country together with all the necessary intermediates within a period of 15 years. The average annual consumption of the 51 dyes in India is 7.3–8.0 million lb., the total annual consumption of all dyes being 14.575 million lb. (Coun. sci. industr. Res. India, *Rep. Dyestuffs explor. Comm.*, 1945, 35).

Table 9 gives the requirements of coal tar raw materials for the production of 51 dyes and their availability in the country.

Of the three essential coal tar hydrocarbons, viz. benzene, toluene, and naphthalene, the first two are available in quantities considerably larger than the requirements. The supply of naphthalene is inadequate but its production can be stepped up to meet the requirements. A third of the quantity of anthracene required is available and the need for the remainder may be obviated by using the naphthalene route to anthraquinone. Carbazole can be obtained by working up the residues left after refining anthracene. Pyridine has to be imported for the time being.

Table 10 gives the requirements and the availability of aliphatic raw materials required for the manufacture of the 51 dyes.

Methanol, acetic acid, and formaldehyde which are not produced in adequate quantities at present in the country have to be imported.

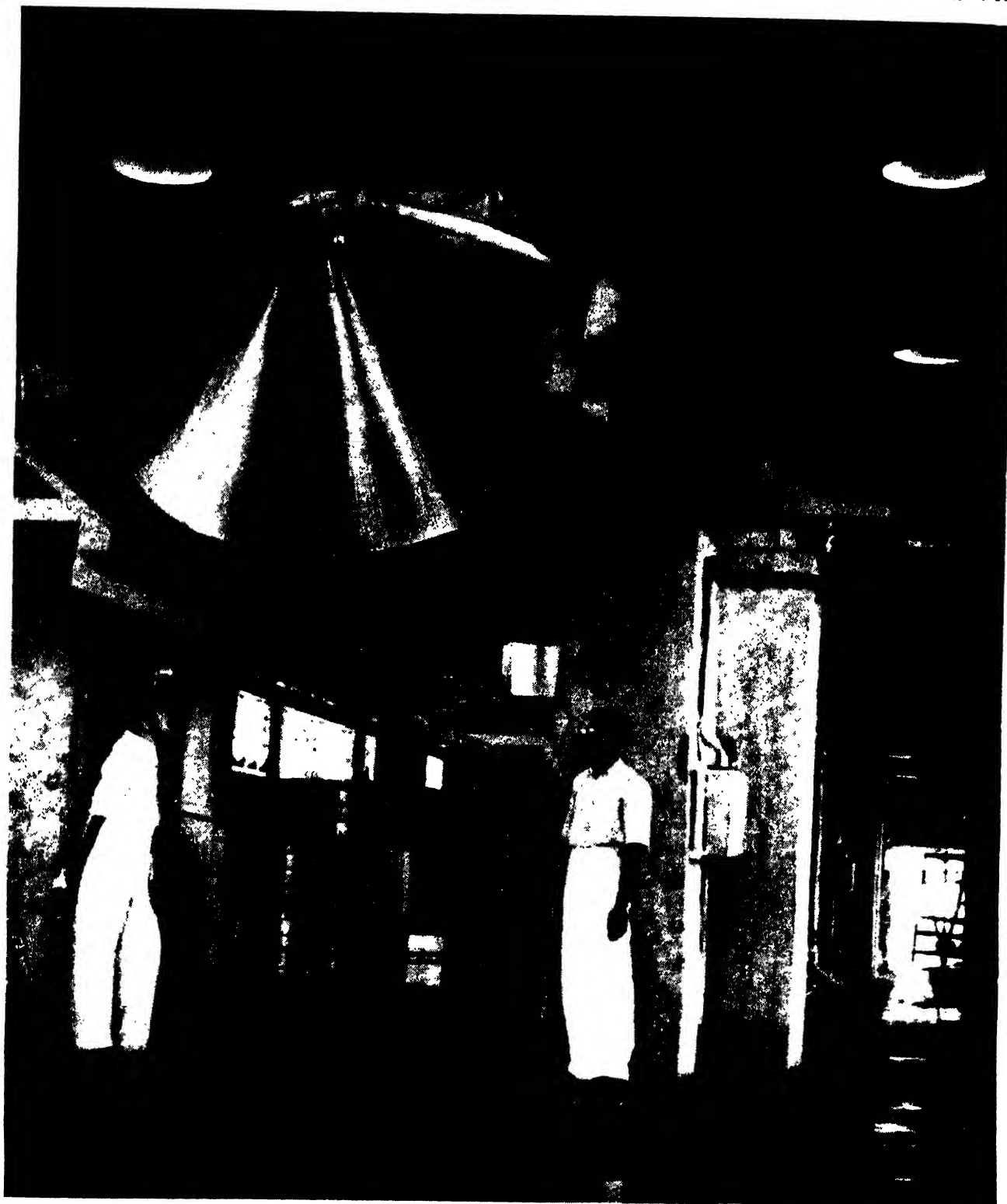
Table 11 gives the availability of inorganic chemicals. Table 12 gives the requirements of basic raw materials required for the manufacture of inorganic chemicals.

The manufacture of synthetic dyes was started in the early years of World War II. There are now nine concerns, viz. Messrs. *Associated Research Laboratories*, Bombay; *International Research Laboratories*, Bombay; *Shree Mahalaxmi Colour & Chemical Co. Ltd.*, Bombay; *National Dyes*, Bombay; *Durga Laboratories*, Bombay;

TABLE 12—REQUIREMENTS OF BASIC RAW MATERIALS FOR THE MANUFACTURE OF INORGANIC CHEMICALS*

| | Qty (tons) |
|--|------------|
| Ammonia | 1,216 |
| Bauxite (55% Al ₂ O ₃) | 546 |
| Bromine | 41 |
| Chlorine | 2,132 |
| Chrome ore (50% Cr ₂ O ₃) | 1,200 |
| Copper | 114 |
| Fluorspar | 13 |
| Iodine, (lb.) | 50 |
| Iron | 501 |
| Lead | 77 |
| Limestone (75% CaCO ₃) | 7,557 |
| Magnesium carbonate | 167 |
| Mercury | 1 |
| Phosphorus | 14 |
| Potassium chloride | 814 |
| Potassium nitrate | 100 |
| Pyrolusite (80% MnO ₂) | 300 |
| Selenium | 5 |
| Sodium chloride (including that used for chlorine) | 26,975 |
| Sodium sulphate | 2,032 |
| Sulphur | 5,528 |
| Zinc | 77 |

* Council sci. industr. Res. India, *Rep. Dyestuffs explor. Comm. (Appendices)*, 1946, 5



BLENDER FOR CORRECTING TONE AND STRENGTH OF DYES

Messrs. Atul Products Ltd., Parnera

National Chemical Industries, New Delhi; Narayan Dyestuffs & Chemical Works Ltd., Calcutta; Indian Chemical Industries, Amritsar; and Atul Products Ltd., Parnera (Bulsar), engaged in the production of dyes. The first six concerns are members of the *Indian Dyestuffs Manufacturers' Association of India*. The total capital invested by them is c. Rs. 25 lakhs. The dyes produced include stabilized azoics (Rapid Fast and Rapidogen types) and solubilized vat dyes (Indigosol types). In addition, the *Associated Research Laboratories* also manufacture developing salts. Their rated production capacity is estimated to be 450,000 lb. of stabilized azoics, 50,000 lb. of indigosols, and 120,000 lb. of developing salts.

The biggest dyestuffs factory in India is *Atul Products Ltd.*, Parnera, which was set up early in 1952. The present capital outlay is Rs. 1.75 crores against an authorized capital of Rs. 5 crores, 10% of which is shared by the *American Cyanamide, Calco Division* who have supplied the various unit process plants, the technical 'know-how', and other forms of assistance. The programme includes the production, initially, of 18 azo dyes (including Congo Red), Sulphur Black, and Alizarin. The estimated annual production capacity is 5 million lb. consisting of: azo dyes, 2 million lb.; sulphur dyes, 1 million lb.; and alizarin dyes, 2 million lb. The factory will be in a position to meet 34.5% of the total requirements of the country when it is run to full capacity.

Manufacture—Most of the raw materials and the intermediates required for the production of dyes are at present imported. The intermediates used by *Atul Products Ltd.* in considerable amounts are: Benzidine, 8-amino-1-naphthol-3,6-disulphonic acid (H acid), 7-amino-1-naphthol-3-sulphonic acid (Gamma acid), 6-amino-1-naphthol-3-sulphonic acid (J acid), urea, sodium naphthionate, dinitrochlorobenzene, and β -naphthol.

Azo dyes—Mono-azo, disazo, and trisazo dyes are produced by *Atul Products Ltd.* The methods adopted are the same as those employed elsewhere. Two reactions involved in the production of azo dyes are: (1) diazotising an aromatic primary amine and (2) coupling the diazonium salt with a phenol or aromatic amine with a free *o* and/or *p* position or with certain other components having reactive positions. Large quantities of ice and common salt are consumed in azo dye manufacture and an ice plant (capacity, 40 tons per day) has been installed in the azo shed of the *Atul Products Ltd.* Filter presses, driers, and mixing and grinding equipment have been provided.

Both direct dyes and acid dyes are produced by *Atul Products Ltd.* Among the former are Congo



Atul Products Ltd., Par

FIG. 24—REACTION TUBS (12,000 GAL.) FOR AZO DYES MANUFACTURE

Red, Direct Blacks, Developed Black B1, Direct Blue 2B, and Direct Green B. The acid dyes produced have the colour range orange, red scarlet, brown, and black (*Chem. Age, Bombay, 1952, ser. 5, 164*).

SULPHUR BLACK—Sulphur Black is prepared by *Atul Products Ltd.* by heating together 2,4-dinitrophenol and sodium polysulphide. The dye is precipitated and purified. The drying is effected in stainless steel double drum dryers. The estimated consumption of sulphur dyes is 24% of all the dyes consumed in India, of which

TABLE 13—PRODUCTION OF COAL TAR DYESTUFFS*
(Qty in lb.)

| | 1950 | 1951 | 1952 |
|-------------------|--------|--------|--------|
| Sulphur Black | | | 17,521 |
| Azo dyes | | | 59,947 |
| Stabilized azoics | 50,937 | 32,166 | 46,113 |
| Solubilized vats | 5,247 | 5,894 | 6,436 |

* *Rep. Minist. Comm. & Industr., Govt. of India, 1951-52, 85; 1952-53, 70*

DYESTUFFS

TABLE 14—IMPORTS OF COAL TAR DYES
(Qty in 1,000 lb.)

| Dyes | 1934/35- 1938/39 (av.) | 1939/40- 1943/44 (av.) | 1945-46 | 1946-47 | 1947-48 | 1948-49 | 1949-50 | 1950-51 | 1951-52 | 1952-53 |
|---------------------------------------|------------------------------|------------------------------|----------|----------|----------|----------|---------|----------|----------|---------|
| Alizarin | 2,302.2 | 919.6 | 247.2 | 1,387.6 | 2,504.1 | 632.4 | 104.6 | 75.4 | 217.9 | 2.1 |
| Congo Red | 2,043.2 | 664.3 | 261.7 | 522.7 | 861.3 | 1,376.8 | 937.9 | 1,412.6 | 1,177.6 | 393.2 |
| Coupling dyes of the naphtha group | | | | | | | | | | |
| Naphthols | 958.6 | 596.4 | 909.0 | 904.6 | 1,434.4 | 1,231.9 | 1,280.4 | 1,205.6 | 1,487.2 | 968.7 |
| Rapid fast colours | 82.4 | 45.6 | 164.0 | 91.3 | 88.0 | 126.8 | 171.7 | 263.6 | 253.9 | 254.3 |
| Bases | 535.8 | 422.2 | 938.9 | 1,356.4 | 1,170.0 | 510.9 | 368.7 | 959.5 | 988.1 | 660.3 |
| Salts | 978.4 | 373.9 | 754.1 | 810.3 | 840.3 | 299.8 | 647.2 | 829.2 | 928.2 | 421.6 |
| Vats | | | | | | | | | | |
| Indigo | 973.5 | 508.0 | 933.8 | 562.4 | 878.6 | 933.0 | 292.4 | 348.3 | 661.3 | 346.7 |
| Vat paste | 199.7 | 221.2 | 182.6 | 378.3 | 656.5 | 470.0 | 217.5 | 257.1 | 343.1 | 79.1 |
| Vat powder | 664.7 | 477.4 | 754.7 | 601.8 | 1,200.8 | 924.7 | 588.4 | 813.9 | 1,191.5 | 670.6 |
| Carbazol Blue | 89.7 | 39.0 | 20.0 | 33.9 | 51.2 | 19.1 | 6.3 | 15.5 | 40.3 | 3.6 |
| Sulphur Black | 3,595.8 | 2,980.7 | 3,938.5 | 1,940.5 | 4,103.1 | 3,316.2 | 502.6 | 3,812.7 | 3,067.5 | 1,147.1 |
| Metanil Yellow | 666.7 | 154.9 | 53.2 | 119.8 | 623.0 | 292.9 | 267.0 | 228.2 | 263.6 | 118.5 |
| Auramine | .. | .. | .. | 8.3 | 13.7 | 16.4 | 0.7 | 34.4 | 39.2 | .. |
| Rhodamines | .. | .. | 0.2 | 8.1 | 2.9 | 36.6 | 11.0 | 23.2 | 17.8 | .. |
| Aniline salts | .. | .. | 642.1 | 609.3 | 305.2 | 197.4 | 169.3 | 538.1 | 628.1 | 11.2 |
| All other dyes | 4,818.0 | 1,863.9 | 4,508.1 | 3,537.2 | 5,798.1 | 4,583.1 | 1,944.0 | 3,133.5 | 4,035.1 | 2,134.2 |
| Total | 17,908.7 | 9,267.1 | 14,308.0 | 12,872.5 | 20,531.3 | 14,968.1 | 7,509.8 | 13,950.8 | 15,340.3 | 7,211.3 |

TABLE 15—AVERAGE PRICE OF IMPORTED DYESTUFFS¹
(Price per lb. in Rs. as. ps.)

| | Germany | U.K. | Switzer- land | Italy | U.S.A. | France | Japan | Other countries ² | Average |
|---------------------------|---------|--------|------------------|--------|---------|---------|--------|---------------------------------|---------|
| 1930/31- 1934/35 (av.) | 1 12 9 | 1 2 3 | 2 10 9 | 1 11 5 | 1 1 3 | 2 10 4 | 2 8 6 | 1 3 10 | 1 7 2 |
| 1935/36- 1939/40 (av.) | 1 12 6 | 2 2 8 | 3 12 0 | 1 15 9 | 1 1 7 | 2 7 10 | 1 3 7 | 0 14 1 | 1 13 6 |
| 1940-41 | 2 15 7 | 3 3 10 | 8 2 9 | 3 15 3 | 3 5 4 | 5 7 8 | 2 6 7 | 2 15 3 | 3 7 4 |
| 1941-42 | .. | 3 15 3 | 12 5 7 | .. | 3 12 10 | .. | 2 7 5 | 3 5 8 | 4 6 3 |
| 1942-43 | .. | 6 0 6 | 18 15 5 | .. | 4 12 6 | .. | 6 14 3 | 3 15 9 | 6 0 3 |
| 1943-44 | .. | 3 4 7 | 16 6 1 | .. | 5 7 1 | .. | .. | 4 13 6 | 7 7 9 |
| 1944-45 | .. | 8 4 5 | 23 3 2 | .. | 5 3 3 | .. | .. | 7 8 2 | 7 5 0 |
| 1945-46 | .. | 5 14 4 | 19 9 3 | .. | 5 8 5 | .. | .. | 8 4 8 | 7 2 5 |
| 1946-47 | 4 7 4 | 6 2 5 | 17 3 5 | 6 13 3 | 6 12 2 | 7 10 9 | .. | 7 11 6 | 7 2 11 |
| 1947-48 | 5 3 3 | 7 7 11 | 16 8 4 | 8 9 0 | 7 3 0 | 9 12 10 | .. | 15 2 0 | 7 10 5 |
| 1948-49 | 7 13 6 | 5 12 7 | 18 2 0 | 7 8 2 | 8 11 6 | 11 2 5 | .. | 22 9 1 | 8 4 9 |
| 1949-50 | 8 12 10 | 9 4 5 | 19 1 9 | 9 1 8 | 13 15 9 | 8 11 4 | .. | 14 14 2 | 10 12 1 |
| 1950-51 | 9 0 3 | 7 6 0 | 17 14 9 | 6 10 7 | 10 1 3 | 10 5 10 | 4 3 8 | 6 10 7 | 8 14 2 |

¹ Comm. & Industr., 1952, 37 (20), 11

² Other countries include: Austria, Hungary, and Russia

Sulphur Black alone forms 21.6%. The annual requirement of Sulphur Black is 3.2 million lb. of which about one-third will be met by this firm.

ALIZARIN—Atul Products Ltd. is in a position to manufacture c. 2 million lb. of 20% alizarin, which fully satisfies the country's requirements of the dye in paste form.

Production and Trade—Table 13 gives the quantity and value of stabilized azoics manufactured in India by the 6 firms belonging to the Dyestuffs Manufacturers' Association of India.

Imports—The major part of the dyestuffs consumed in India is imported. Table 14 gives the imports of coal tar dyes into India in recent years.

Imports are subject to 12% *ad valorem* duty.

Germany was the principal supplier of dyes till the outbreak of World War II. U.S.A. replaced Germany as a leading supplier closely followed by U.K. during and immediately after World War II. More recently, however, imports from Germany have increased while imports from U.S.A. have diminished. Other suppliers of dyes to India are Switzerland, France, Netherlands, Italy, Czechoslovakia, Poland and Japan.

Prices—The average prices of dyestuffs imported into India have maintained an upward trend since the last two decades. Table 15 gives the average prices of dyestuffs imported from various countries during 1930-1950.

E

ELECTRICAL INDUSTRIES

Electrical industries may be broadly divided into two categories: (1) heavy electrical industries and (2) light electrical industries. These include generators, turbo-generators, alternators and dynamos, motors, switchgears, transformers, electrical fittings, domestic appliances, electric lamps, electric fans, batteries and accumulators, insulators, carbons, wires and cables, radio and wireless apparatus, and instruments.

The electrical industry in India is of recent origin, having come into existence only after the termination of World War I. Subsequent to the war and during the depression period, the dumping of cheap electrical goods from countries like Japan and Germany acted as a set-back to the development of the Indian industry.

TABLE 1—IMPORTS OF ELECTRICAL MACHINERY AND APPARATUS
(Val. in lakh Rs.)

| | Machinery | Instruments | Wireless apparatus | Total |
|-----------------------|-----------|-------------|--------------------|---------|
| 1934/35-1938/39 (av.) | 254.1 | 314.3 | 33.7 | 602.1 |
| 1939/40-1943/44 (av.) | 234.0 | 218.1 | 39.5 | 491.6 |
| 1944-45 | 301.6 | 261.1 | 13.2 | 575.9 |
| 1945-46 | 321.5 | 453.3 | 26.0 | 800.8 |
| 1946-47 | 517.4 | 595.9 | 200.7 | 1,314.0 |
| 1947-48 | 778.2 | 972.2 | 361.5 | 2,111.9 |
| 1948-49 | 1,277.7 | 1,143.7 | 126.2 | 2,547.6 |
| 1949-50 | 1,490.3 | 1,380.1 | 149.7 | 3,020.1 |
| 1950-51 | 1,199.9 | 966.7 | 137.9 | 2,304.5 |
| 1951-52 | 1,620.3 | 1,035.9 | 206.9 | 2,863.1 |
| 1952-53 | 1,714.8 | 1,381.4 | 149.9 | 3,246.1 |

The first electrical industry to be set up was the fan industry in Calcutta in 1921. It was closely followed by the starting of a factory for the manufacture of cables and wires in Tatanagar. The first lamp manufacturing factory was established in Calcutta in 1932. The manufacture of electric motors, transformers, insulators, and batteries was taken up much later.

The electrical manufacturing industry in India is now fairly well established. In several of its branches, it is in a position to meet the country's demands; in a few, it is able to effect exports.

TABLE 2—IMPORTS OF ELECTRICAL MACHINERY*
(Val. in lakh Rs.)

| | Generators, alternators, and dynamos | Turbo-generating sets | Others† |
|-----------------------|--------------------------------------|-----------------------|---------|
| 1934/35-1938/39 (av.) | 28.2 | 14.8 | 90.5 |
| 1939/40-1943/44 (av.) | 23.9 | 8.6 | 60.9 |
| 1944-45 | 30.4 | 10.4 | 62.1 |
| 1945-46 | 33.1 | 6.0 | 79.8 |
| 1946-47 | 94.1 | 22.4 | 146.2 |
| 1947-48 | 157.2 | 39.4 | 178.1 |
| 1948-49 | 217.8 | 34.4 | 332.9 |
| 1949-50 | 229.7 | 59.4 | 354.2 |
| 1950-51 | 156.3 | 64.7 | 314.1 |
| 1951-52 | 237.9 | 152.4 | 556.4 |
| 1952-53 | 246.3 | 129.8 | 523.2 |

Refers to items which are not at present manufactured in India

Details not known; may contain items which are manufactured in the country on a small scale

TABLE 3—IMPORTS OF ELECTRICAL INSTRUMENTS AND APPARATUS*
(Val. in lakh Rs.)

| | Condensers | Bells | Instruments other than telegraphic and telephonic | Electro-medical apparatus | Switch boards other than telephone and telegraph | Other electrical goods† |
|-----------------------|------------|-------|---|---------------------------|--|-------------------------|
| | | | Meters | Others‡ | | |
| 1934/35-1938/39 (av.) | 0.5 | 0.7 | 11.7 | 5.9 | 4.8 | 36.9 |
| 1939/40-1943/44 (av.) | 1.1 | 0.8 | 11.4 | 4.3 | 5.3 | 25.9 |
| 1944-45 | 3.0 | 0.6 | 4.9 | 4.1 | 5.8 | 32.0 |
| 1945-46 | 5.0 | 0.9 | 7.6 | 9.7 | 7.9 | 51.7 |
| 1946-47 | 3.0 | 6.4 | 27.5 | 28.7 | 13.7 | 118.5 |
| 1947-48 | 6.8 | 2.9 | 76.2 | 26.4 | 31.0 | 189.0 |
| 1948-49 | 4.4 | 2.2 | 107.9 | 21.8 | 31.4 | 165.1 |
| 1949-50 | 3.1 | 3.0 | 86.2 | 19.4 | 26.1 | 167.3 |
| 1950-51 | 2.3 | 3.3 | 64.2 | 16.8 | 34.5 | 143.0 |
| 1951-52 | 5.1 | 1.3 | 107.4 | 23.8 | 36.3 | 200.9 |
| 1952-53 | 5.6 | 1.4 | 67.2 | 20.8 | 28.7 | 223.0 |

* Refers to items which are not at present manufactured in India

† Details not known; may contain some items which are manufactured in the country on a small scale

ELECTRICAL INDUSTRIES

Heavy electrical equipments, electric carbons, arc lamps, measuring instruments, electro-medical apparatus, and many components of electrical equipments are still imported.

Table 1 gives imports of electrical machinery, instruments, and wireless apparatus into India. Table 2 gives the imports of machinery and Table 3 of instruments and apparatus not generally manufactured in India.

The future development of electrical machinery and equipment manufacturing industries is linked up with the schemes formulated by the Planning Commission. The prospects depend upon the availability of power supply, expansion of telecommunication, air-conditioning, wireless service, and railway traffic, development of industries, such as textiles and automobiles, and increased use of electricity in agricultural operations.

Batteries and Accumulators

DRY CELLS

Dry batteries have the advantage of greater portability over wet batteries. They have, therefore, found diverse uses in gadgets and instruments used for civil and defence purposes. Dry batteries are used in flashlights, cycle lamps, radio sets, post

and telegraph equipment, deaf-aid apparatus, medical instruments, and meteorological instruments. In mobile telecommunication equipment required by the defence services, dry batteries play an important role.

The first factory for the manufacture of dry batteries in India was set up by the *Eveready Company* of U.K. in 1926 at Cossipore, Calcutta. The factory was acquired by the *National Carbon Co.* of U.S.A. in 1936. *Estrela Batteries Ltd.*, Bombay was the first Indian firm to undertake production of dry batteries. The demand for dry batteries increased considerably during World War II and was met almost wholly by indigenous production. Both *National Carbon Co. (India) Ltd.* and *Estrela Batteries Ltd.* expanded their capacity during and after the war. The industry was given protection in 1947 and since then 2 more units—*Sunbeam Electrical Industries Ltd.*, Bombay and *Solar Batteries and Flashlights Ltd.*, Bombay—have come into production.

Table 4 gives the annual installed capacity of the industry as assessed by the Tariff Board (1950). According to the Development Wing of the Ministry of Commerce and Industry, the annual

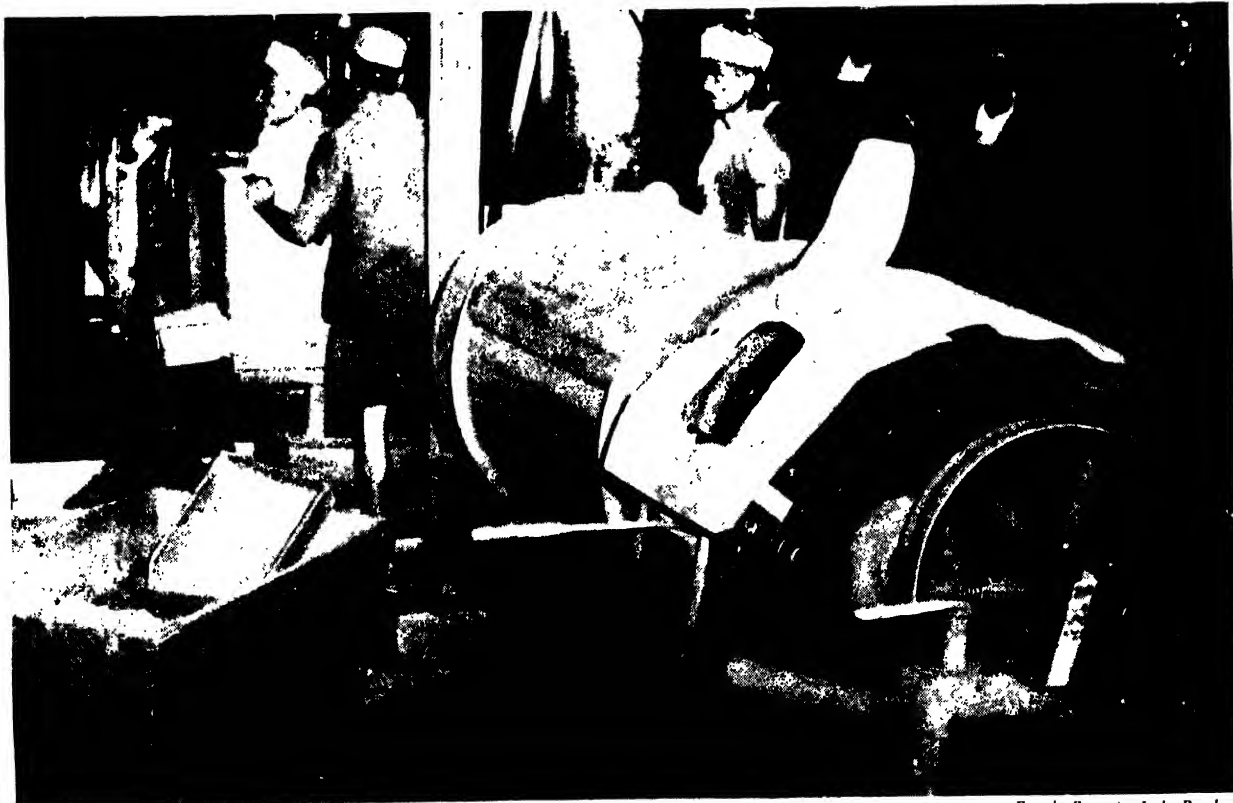
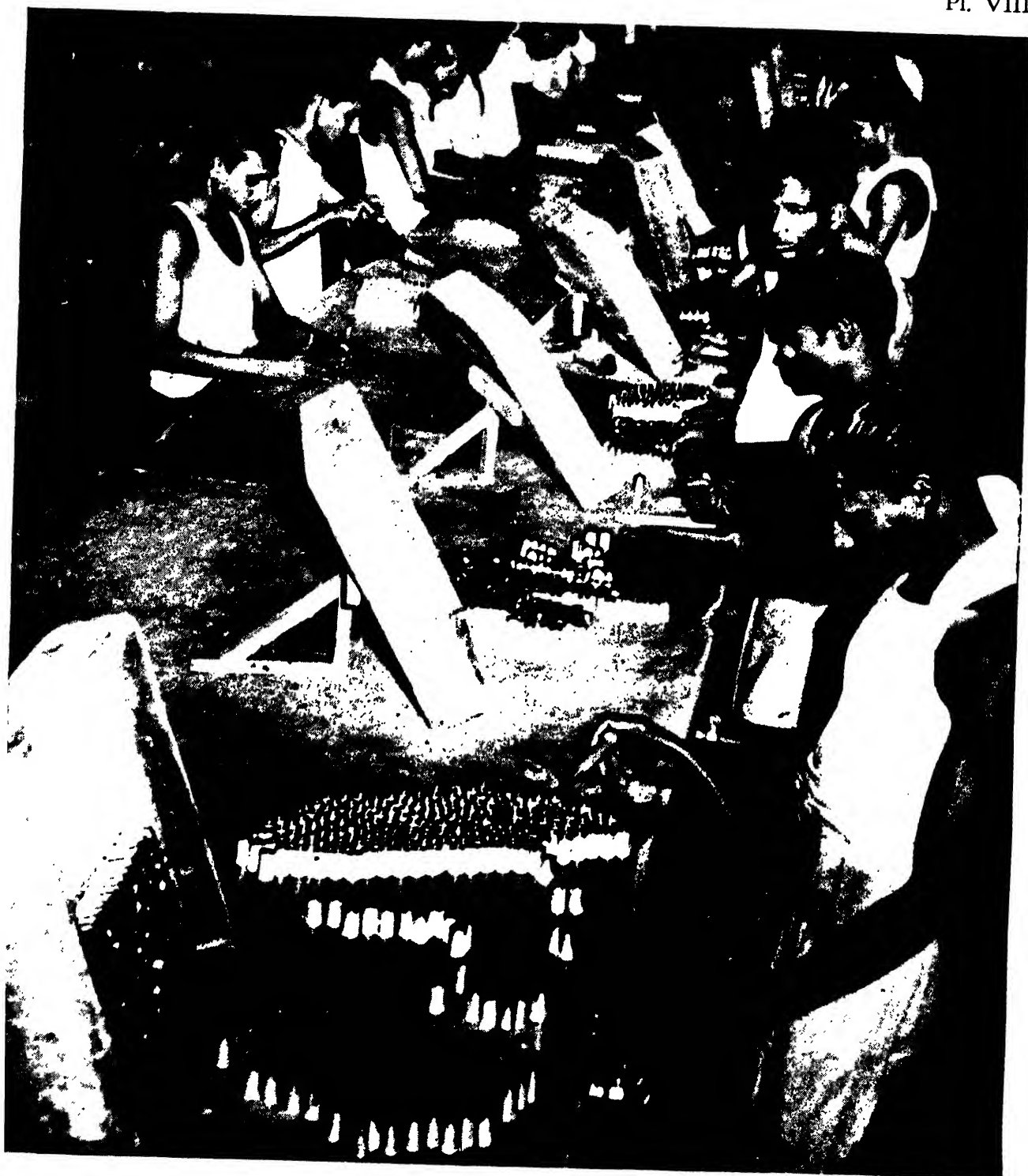


FIG. 25—DRY CELL MANUFACTURE: DEPOLARIZER MIXING

Estrela Batteries Ltd., Bombay



SEALING AND REFLAMING OF DRY CELLS

Messrs. Estrela Batteries Ltd., Bombay

TABLE 4—INSTALLED CAPACITY OF THE DRY CELL INDUSTRY*

| | Qty (no.) |
|---|--------------|
| National Carbon Co. (India) Ltd., Calcutta | 205,000,000 |
| Estrela Batteries Ltd., Bombay | 40,000,000 |
| Sunbeam Electrical Industries Ltd., Bombay | 10,000,000 |
| Solar Batteries & Flashlights Ltd., Bombay | 30,000,000 |
| Total | 285,000,000 |

* Indian Tariff Bd, Rep. Continuance of Protection to the Dry Battery Industry, 1950, 8

rated capacity at the end of 1952 was 196,500,000 cells.

The capital invested and the labour employed in the industry are respectively Rs. 120 lakhs and 2,500 persons.

The National Carbon Co. (India) Ltd. propose to undertake the manufacture of layer-built batteries (annual capacity, 24 million cells) and standard cells; their total capacity per annum for all types of dry cells would increase by 25 million cells. The Directorate of Technical Development, M.G.O. Branch, Army Headquarters, are considering plans for the manufacture of layer-built cells.

Raw materials—The raw materials used in the manufacture of dry batteries are manganese dioxide, graphite, and carbon rods. Electrolyte materials consist of chlorides of ammonium, zinc, calcium, magnesium, and mercury, all of high purity, used singly or in combination. Containers, caps, and connecting strips are made from zinc and brass sheets.

The industry is dependent to a considerable extent on imported raw materials. It is estimated that the proportion of indigenous to imported raw materials is 29:71. The more important among the imported materials are: manganese dioxide, graphite, lamp black, carbon, zinc sheets, ammonium chloride, zinc oxide, zinc chloride, calcium chloride, and mercuric chloride.

Not much progress has been made in the utilization of Indian raw materials or in the adoption of improved techniques of manufacture. Indigenous manganese dioxide ore is not suitable. It should, however, be possible to improve the quality of the ore by suitable treatment. Fairly satisfactory results have been obtained by blending indigenous ore with an equal quantity of imported manganese dioxide. Estrela Batteries Ltd. are at present reported to be using equal quantities of indigenous and imported ores. There has been little progress also in regard to the utilization of indigenous graphite for carbon rods. Indian

graphite can be purified by flotation to a grade of purity suitable for use in dry batteries. Though dependence on imports cannot be obviated entirely, there are prospects of reaching self-sufficiency in respect of such items as ammonium chloride, zinc chloride, clip boards, pulp boards, corrugated cardboards and sheets, and printed labels (Venkateswarulu, *J. Indian chem. Soc. industr. Edn*, 1944, 1, 96).

Production and Prices—Table 5 gives the production of dry cells in India.

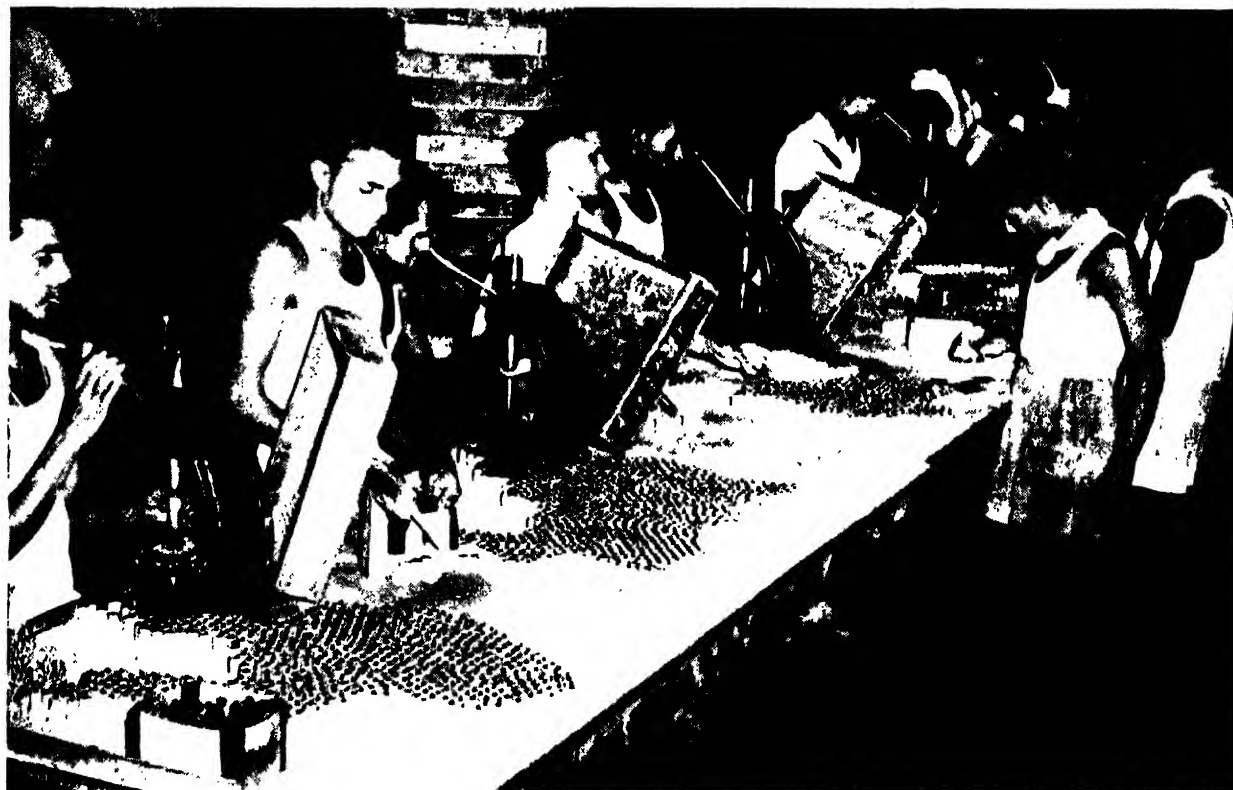
Of the total production of 152.219 million cells during 1949, 121.44 millions were produced by the National Carbon Co. (India) Ltd., 27.9 millions by Estrela Batteries Ltd., and 2.34 millions by Sunbeam Electrical Industries Ltd.

The Tariff Board estimated the fair selling price in 1950-51 of 1,000 standard cells at Rs. 225.20 (excluding Rs. 10 for prejudice) on the basis of the production of Estrela Batteries Ltd. This includes Rs. 127.55 for materials, Rs. 24.18 for



Estrela Batteries Ltd., Bombay

FIG. 26—PREPARATION OF ELECTROLYTE



Estrela Batteries Ltd., Bombay

FIG. 27—DRY CELL MANUFACTURE: TOPWASHING AND CAPPING

labour, Rs. 67.60 for overheads, and Rs. 5.87 for profit (Indian Tariff Bd, *Rep. Continuance of Protection to the Dry Battery Industry*, 1950, 13).

Table 6 gives the imports of batteries into India. Prior to World War II, the bulk of dry batteries was imported from U.S.A.; Germany came second, followed by Hongkong, U.K., and Japan. During World War II, there were practically no imports. A ban on imports was imposed in 1947 owing primarily to the shortage of foreign exchange. Only special types, not at present produced in India, such as deaf-aid batteries, are allowed to be

TABLE 6—IMPORTS OF BATTERIES

| | Val. (lakh Rs.) |
|-----------------------|--------------------|
| 1934/35-1938/39 (av.) | 21.63 |
| 1939/40-1943/44 (av.) | 8.07 |
| 1944-45 | 3.07 |
| 1945-46 | 5.12 |
| 1946-47 | 6.17 |
| 1947-48 | 8.03 |
| 1948-49 | 19.29 |
| 1949-50 | 47.64 |
| 1950-51 | 17.00 |
| 1951-52 | 24.26 |
| 1952-53 | 16.84 |

TABLE 5—PRODUCTION OF DRY CELLS

| | Qty (no.) | Val. (lakh Rs.) |
|------|--------------|--------------------|
| 1946 | 87,965,242 | n.a. |
| 1947 | 87,917,226 | n.a. |
| 1948 | 123,830,055 | 288.5 |
| 1949 | 152,218,999 | 348.5 |
| 1950 | 138,177,491 | 316.0 |
| 1951 | 143,358,805 | 329.0 |
| 1952 | 130,181,499 | n.a. |

n.a. not available

imported. Imports of dry batteries are subject to a protective duty of 31½% *ad valorem*.

Tables 7 and 8 give imports of dry batteries and parts from U.K. and U.S.A. into India.

Exports—India exported 3,925,814 cells in 1947, 1,193,174 cells in 1948, and 79,372 cells in Jan.-Sept. 1949. In 1948, dry cells manufactured by *National Carbon Co. (India) Ltd.* were exported to Burma, Turkey, Egypt, Ceylon, Lebanon, and Saudi Arabia; dry cells produced by *Estrela Batteries*

TABLE 7—IMPORTS OF BATTERIES FROM U.K.*

| | Qty (number of cells) | | | Val. (£) | | |
|--|-----------------------|-----------|---------|------------|--------|--------|
| | 1948 | 1949 | 1950 | 1948 | 1949 | 1950 |
| For radio | 5,156,552 | 1,566,106 | 924,990 | 55,033 | 17,900 | 15,268 |
| For telephone, telegraph, & signalling | 26,741 | 102,575 | 15,442 | 5,758 | 17,912 | 3,819 |
| For all other purposes | 9,164 | 41,152 | 7,085 | 437 | 4,907 | 2,192 |
| Parts other than carbon (cwt.) | 1,332 | 1,932 | 1,361 | 8,875 | 21,162 | 16,432 |

* Tr. U.K.

TABLE 8—IMPORTS OF DRY BATTERIES FROM U.S.A.*
(Qty in numbers and val. in \$)

| | Flashlights | | Multiple cells | | Primary, dry & wet cells | |
|------|-------------|-------|----------------|-------|--------------------------|--------|
| | Qty | Val. | Qty | Val. | Qty | Val. |
| 1948 | 137,488 | 7,321 | 5,307 | 922 | 3,264 | 6,486 |
| 1949 | 46,752 | 2,307 | 48,294 | 2,209 | 20,150 | 55,849 |
| 1950 | 62,664 | 2,841 | 76,197 | 3,619 | 1,248 | 1,111 |
| 1951 | | | 41,289 | 2,214 | | |

U.S. Exports of Domestic & Foreign Merchandise

TABLE 9—ESTIMATED DEMAND FOR DRY CELLS IN 1955-56*

| | Qty (no. in millions) |
|----------------------|--------------------------|
| Flashlight batteries | 175 |
| Defence | 25 |
| Radio | 100 |
| Export | 20 |
| Total | 320 |

* The Planning Comm., *Programmes of Industrial Development 1951-56, 1953, 85*

Estrela Batteries Ltd., Bombay

* FIG. 28—TESTING OF DRY CELLS

Ltd. were exported to Burma. Exports to Burma were discontinued in 1949 due to restrictions by the Government of Burma.

The Tariff Board estimated the demands for 1950, 1951, and 1952 at 180, 200, and 220 million cells, respectively. The estimate of the demand included requirements of dry battery radios, assessed at 200,000 batteries in 1950 by the All-India Radio Merchants' Association, Bombay (Indian Tariff Bd, *Rep. Continuance of Protection to the Dry Batteries Industries, 1950, 7*). The actual consumption of dry cells was 131.6 millions in 1948-49, 170.0 millions in 1949-50, and 147.5 millions in 1950-51. According to the Planning Commission, the demand for dry cells is expected to increase to 320 millions by 1955-56 (Table 9).

(See also With India, Pt I, 121)

ACCUMULATORS

The first attempt to manufacture accumulators or storage batteries was made in 1931 by the *Tropical Accumulators Ltd.*, Calcutta. By 1939, other factories, such as *Bharat Battery Manufacturing Co. Ltd.*, *Electro Chemical Industries*, *Indian Battery Manufacturing Co. Ltd.*, *Eastern Accumulators Co.*, and *Majumdar Battery Co. (India) Ltd.* were established in Calcutta. The units were small and the total production could meet only a small fraction of the demand. During World War II, various attempts were made to expand the indigenous industry to meet the demand of the defence services. Manufacturing concerns which came into existence during this

ELECTRICAL INDUSTRIES

TABLE 10—REGIONAL DISTRIBUTION OF MOTOR VEHICLE BATTERY INDUSTRY*
(Qty in numbers)

| | No. of units (1951) | Annual rated capacity (1951) |
|----------------------------|------------------------|---------------------------------|
| West Bengal (Calcutta) | 7 | 225,100 |
| Bombay, including Kolhapur | 8 | 232,100 |
| Mysore | 2 | 52,620 |
| Madras | 1 | 25,000 |
| Delhi | 1 | 3,600 |
| Total | 19 | 538,420 |

* The Planning Comm., *Programmes of Industrial Development 1951-56, 1953, 88*

period are: *Estrela Batteries Ltd.*, Bombay (1939), *Standard Batteries Ltd.*, Bombay (1943), and *Chloride Electrical Storage Co. (India) Ltd.*, Calcutta (1945). The *General Motors (India) Ltd.*, Bombay constitutes the most important unit established in the post-war period.

The industry was given protection with effect from November 1948 for 3 years. Since then the motor vehicle battery industry has recorded satisfactory progress. The number of organized units rose from 11, with an annual rated capacity of 265,900 batteries in 1948, to 13 with an annual rated capacity of 412,000 batteries in 1949. The capacity increased to 538,420 batteries per annum on single shift operation in 1951 with the expansion of some of the existing units and the coming into production of 5 new units, viz. *Free India Dry Accumulators, Ltd.*, Calcutta (30,000); *Mysore Electrochemical Works*, Bangalore (20,000); *Oldham and Son (India) Ltd.*, Madras (25,000); *Kolhapur Auto Works*, Kolhapur (9,000); and *Modern Battery Manufacturing Co.*, Bombay (5,000), the numbers within brackets indicating rated installed capacity. Taking into account the *Acme Battery Manufacturing Co. Ltd.*, Delhi-Shahdara, the rated capacity of the industry is now 538,420. Table 10 gives the regional distribution of vehicle battery industry (The Planning Comm., *Programmes of Industrial Development 1951-56, 1953, 87*).

Raw materials—The principal raw materials required for the manufacture of motor vehicle batteries are: containers with covers and vent plugs, lead, antimony, oxides of lead (red lead and litharge), sulphuric acid, and separators. The industry is dependent on imports for lead, asbestos fibre, and veneers.

The containers most commonly employed are of rubber composition; asbestos compositions are used by *Associated Battery Makers*. Containers are produced in a variety of sizes and a major part of the requirements of the industry are met

by indigenous production; special sizes, for which the demand is limited, are obtained by import. Table 11 gives the annual installed capacity and actual production of containers in 1951. The *Firestone Tyre & Rubber Co. of India, Ltd.*, Bombay propose to expand the production capacity to 180,000 containers per annum.

Lead required for the production of plates is imported from Australia. Attempts have been made to economize the use of lead by altering the designs of plates, connectors, and connection posts. Antimony required for alloying with lead, oxides of lead, and sulphuric acid are obtained from indigenous sources (Tariff Comm., *Rep. Continuance of Protection to the Motor Vehicle Battery Industry, 1952, 10*).

Battery separators are made of wood, ebonite, fibre glass, or micro-porous rubber. Separators made from the woods of Douglas fir (*Pseudotsuga taxifolia*) or Port Orford cedar (*Chamaecyparis lawsoniana*) are imported, principally from U.S.A. and Canada. Some of the manufacturers import veneers and produce separators by grooving and treating. Experiments carried out at the Forest Research Institute, Dehra Dun show that cypress (*Cupressus torulosa*) and champ (*Michelia champaca*) can be used as substitutes for Port Orford cedar. In physical and electrical properties and in performance, separators made of fir (*Abies pindrow*) and spruce (*Picea morinda*) are in no way inferior to Port Orford cedar; deodar (*Cedrus deodara*) comes next; kail separators (from *Pinus excelsa*) are weak in mechanical strength and may be used in batteries of short life. A number of factories equipped with machinery for slicing, grooving, and chemical treatment of timber has been established since 1949 for the production of separators. Table 12 gives the annual rated capacity and production of separators in India (Tariff Comm., *Rep. Continuance of Protection to the Motor Vehicle Battery*

TABLE 11—ANNUAL RATED CAPACITY AND PRODUCTION OF MOTOR VEHICLE BATTERY CONTAINERS*

| | Capacity (no.) | Production in 1951 (no.) |
|--|-------------------|--------------------------------|
| <i>Associated Battery Makers</i> | 1,00,000 | 95,000 |
| <i>Standard Batteries</i> | 1,20,000 | 63,748 |
| <i>Bharat Batteries</i> | 36,000 | 15,000 |
| <i>Firestone Tyre & Rubber Company</i> | 1,20,000 | 73,523 |
| Total | 3,76,000 | 2,47,271 |

* Tariff Comm., *Rep. Continuance of protection to the Motor Vehicle Battery Industry, 1952, 9*

ELECTRICAL INDUSTRIES

TABLE 12—ANNUAL RATED CAPACITY AND PRODUCTION OF BATTERY SEPARATORS*

| | Capacity (no. in millions) | Production (no. in millions) |
|---|-------------------------------|---------------------------------|
| <i>Leela Separators Mfg. Co. Ltd., Delhi</i> | 10.0 | 2.4 |
| <i>Battery Separators Ltd., Delhi</i> | 4.0 | 1.2 |
| <i>India Veneers & Separators Ltd., Dalhousie</i> | 6.0 | 1.2 |
| <i>Kalson Carpenters, Srinagar</i> | 2.0 | 1.2 |
| <i>Hindustan National Industries, Amritsar</i> | 3.6 | 0.6 |
| Total | 25.6 | 6.6 |

* Tariff Comm., *Rep. Continuance of Protection to the Motor Vehicle Battery Industry, 1952, 12*

TABLE 13—REQUIREMENTS OF PRINCIPAL RAW MATERIALS (FOR 340,000 BATTERIES)*

| | Qty (tons) |
|---|---------------|
| Lead | 2,500 |
| Antimony | 175 |
| Lead oxides | 2,700 |
| Rubber compound for container, cover & plug | 1,600 |
| Separators (no. in millions) | 17 |

* The Planning Comm., *Programmes of Industrial Development 1951-56, 1953, 89*

TABLE 14—PRODUCTION OF STORAGE BATTERIES

| | Qty (no.) |
|------|--------------|
| 1946 | 27,074 |
| 1947 | 70,028 |
| 1948 | 110,000 |
| 1949 | 107,065 |
| 1950 | 187,121 |
| 1951 | 212,621 |
| 1952 | 157,843 |

Industry, 1952, 11; Indian For. Bull., 1950, No. 147, 4).

Based on values, only 20% of the raw materials required by the industry is derived from indigenous sources. Table 13 gives the average requirements of the principal raw materials for producing 340,000 batteries (The Planning Comm., *Programmes of Industrial Development 1951-56, 1953, 88*).

TABLE 15—REGIONAL PRODUCTION OF STORAGE BATTERIES*
(Qty in numbers)

| | 1949 | 1950 | 1951 |
|----------------------------|----------------|----------------|----------------|
| West Bengal (Calcutta) | 58,557 | 79,458 | 110,862 |
| Bombay, including Kolhapur | 48,752 | 108,422 | 133,182 |
| Mysore | 2,992 | 879 | 3,940 |
| Madras | .. | .. | 3,600 |
| Delhi | .. | .. | n.a. |
| Total | 110,301 | 188,759 | 251,584 |

* The Planning Comm., *Programmes of Industrial Development 1951-56, 1953, 88*

TABLE 16—IMPORTS OF ACCUMULATORS (INCLUDING PARTS)

| | Val. (lakh Rs.) |
|-----------------------|--------------------|
| 1934/35-1938/39 (av.) | 6.97 |
| 1939/40-1943/44 (av.) | 7.85 |
| 1944-45 | 13.81 |
| 1945-46 | 12.07 |
| 1946-47 | 18.46 |
| 1947-48 | 18.72 |
| 1948-49 | 13.31 |
| 1949-50 | 35.40 |
| 1950-51 | 24.31 |
| 1951-52 | 38.79 |
| 1952-53 | 29.61 |

TABLE 17—IMPORTS OF ACCUMULATORS FROM U.K.

| | Qty (no.) | | | Val. (£) | | |
|--|-----------|--------|--------|----------|---------|---------|
| | 1948 | 1949 | 1950 | 1948 | 1949 | 1950 |
| For motor vehicles, no. of batteries | 49,250 | 67,651 | 2,506 | 148,825 | 228,396 | 9,006 |
| For traction, lead acid type, no. of cells | 117 | 1,189 | 504 | 846 | 10,525 | 7,928 |
| Other portable accumulators, no. of cells | 32,385 | 31,042 | 24,726 | 109,910 | 108,936 | 220,966 |
| Stationary, lead acid type, no. of cells | 5,408 | 34,338 | 5,796 | 29,174 | 154,454 | 63,135 |
| Parts and accessories, cwt. | 12,960 | 24,955 | 15,587 | 150,029 | 290,554 | 218,623 |

* Tr. U.K.

ELECTRICAL INDUSTRIES

Production—Table 14 gives the production of storage batteries during the period 1946–52. Table 15 gives the production in the different regions of India during 1949, 1950, and 1951.

In addition to the production in organized factories, several small scale units exist in various parts of the country for assembling batteries from spare plates. The total output of such units is estimated at 50,000 batteries per annum (Tariff Comm., *Rep. Continuance of Protection to the Motor Vehicle Industry*, 1952, 16).

The quality of Indian batteries compares favourably with that of imported batteries.

Tables 16–18 give imports of accumulators and parts into India. Imports of accumulators not otherwise specified are subject to a revenue duty of 31½% *ad valorem*. Imports of storage batteries for motor vehicles and parts are subject to a protective duty of 80% *ad valorem* plus 5% of the total duty for articles of British manufacture.

Batteries produced in India are exported on a limited scale.

The demand for storage batteries, which was of the order of 60,000 units before World War II, was met almost entirely through imports. The demand during 1948–50 was about 250,000 batteries per annum. On the basis of the number of cars

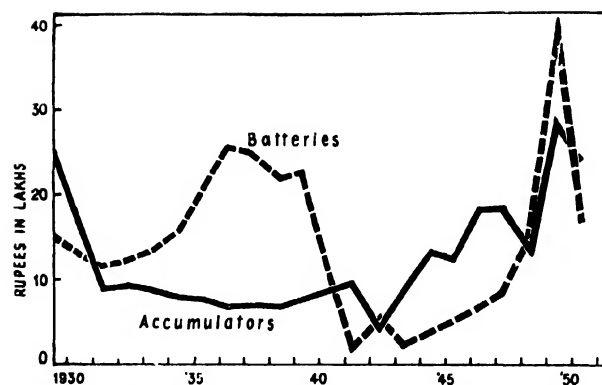


FIG. 29—IMPORTS OF BATTERIES AND ACCUMULATORS

and trucks on roads, the Development Wing of the Ministry of Commerce and Industry estimates the present demand at c. 275,000 per annum. According to the Planning Commission, the requirements of batteries for motor vehicles, including exports, is estimated to be 400,000 in 1955–56 (The Planning Comm., *Programmes of Industrial Development 1951–56*, 1953, 89).

Table 19 gives fair ex-works prices of 6v/16 plate batteries with landed costs of similar imported batteries (Tariff Comm., *Rep. Continuance of Protection to the Motor Vehicle Industry*, 1952, 30)

(See also With India, Pt I, 121)

Carbons

Carbon has found numerous applications in electrical industry as it is a conductor of electricity and it does not soften or weaken even at the high temperature of the electric arc; it has a high melting point, c. 3,500°. Carbon stands supreme in these properties and no other material even approaches it. Carbon is resistant to corrosion and attack by chemicals.

Electric carbons may be classified under furnace electrodes, arc light or illuminating carbons, carbon brushes, battery carbons, and carbon specialities, such as carbon resistors and telephone carbons.

FURNACE ELECTRODES

Electrodes are used in high temperature furnaces required for the manufacture of steel, copper, brass, aluminium alloys, ferro-alloys, and for nitrogen fixation and electrothermic furnaces used in the manufacture of calcium carbide, silicon carbide, graphite, etc.

Raw materials—The raw materials for the manufacture of electrodes are mainly the body material and the binding material. Anthracite coal is mostly employed as body material for large electrodes and petroleum coke for reduction electrodes (e.g. manufacture of aluminium). The

TABLE 18—IMPORTS OF STORAGE BATTERIES FROM U.S.A.*

| | 6 amp, 12 V | | Other types | |
|------|-------------|-----------|-------------|-----------|
| | Qty (no.) | Val. (\$) | Qty (no.) | Val. (\$) |
| 1948 | 20,226 | 160,805 | 12,624 | 109,535 |
| 1949 | 4,899 | 83,517 | 4,127 | 118,355 |
| 1950 | 359 | 14,693 | 1,093 | 12,911 |
| 1951 | 654 | 21,820 | 2,170 | 50,410 |

* U.S. Exports of Domestic & Foreign Merchandise

TABLE 19—FAIR PRICE OF INDIGENOUS BATTERIES AND LANDED COST OF IMPORTED (FROM U.K.) BATTERIES* (Val. in Rs.)

| | 6v/15 plates | | 6v/17 plates | |
|---|--------------|------------|--------------|------------|
| | Aug. 1951 | March 1952 | Aug. 1951 | March 1952 |
| C.i.f. | 43.187 | 60.000 | 46.406 | 60.000 |
| Customs duty | 34.550 | 48.000 | 37.125 | 48.000 |
| Surcharge | 1.727 | 2.400 | 1.856 | 2.400 |
| Clearing charges | 1.438 | 1.438 | 1.470 | 1.470 |
| Landed cost | 80.902 | 111.838 | 86.857 | 111.870 |
| Landed cost, ex-duty | 44.625 | 61.438 | 47.876 | 61.470 |
| Fair ex-works price of indigenous batteries | 54.009 | 54.009 | 60.890 | 60.890 |

* Tariff Comm., *Rep. Continuance of Protection to the Motor Vehicle Battery Industry*, 1952, 30

characteristics of a good body material are: low ash, high fixed carbon, low volatile matter, and high real density. The ash content influences the conductivity and if high, the manufactured products are contaminated. In the production of electrodes materials other than fixed carbon are eliminated and binding materials with low volatile matter and high fixed carbon content are employed. High real density is desirable as a dense material is more difficult to oxidize than a light material. The requirements, however, vary according to the purpose for which the furnace is employed. Thus in the manufacture of aluminium, a high ash content in the electrode is objectionable, whereas in the manufacture of calcium carbide a high ash content is not objectionable. In the manufacture of graphite electrodes, a fair amount of ash in the body material is desirable as the metallic impurities help in graphitizing the carbon.

The binding materials used are tar, electrolytic pitch, and coal tar pitch. The material is tested for melting and softening points, if it is a solid, and for viscosity, free carbon, and coking value, if it is a liquid. Coal tar pitch should contain at least 40% fixed carbon and should be of the highest quality. Coal tar pitch leaves a heavy dense coke; asphaltum pitch leaves a heavy but porous and friable coke. The melting point of pitch should be less than 150°F.

Manufacture—Three types of electrodes are in use; they are: (1) amorphous carbon electrodes, (2) graphite electrodes, and (3) Soderberg electrodes. The same raw materials are used for carbon electrodes and graphite electrodes; the difference lies in processing, shaping, and degree of baking of shaped articles.

The selected body material is crushed and calcined in retorts or calcining furnaces. Calcination is necessary because (1) green or uncalcined material cannot be bonded to form electrodes of the required density; (2) calcined material is easier to mould or extrude; (3) in the operation of baking, volatile matter is expelled if green material is employed and this gives a porous electrode; (4) uncalcined material has poor conductance; and (5) calcined material is of high density which is required for resisting oxidation. Electric calciners yield a denser product as the material is slightly graphitized, thus resulting in a material of low resistivity; calcining in gas-fired furnaces is cheaper. Calcined body material should have the following characteristics: volatile matter, <0.5%; moisture, <0.3%; and resistivity, 0.05 ohm/inch cube (by measuring the drop in voltage at a constant temperature through a definite volume of material). The material is crushed in roll crushers and pulverized. Hard pitch is ground coarse in

corrugated roll crushers and then in rotary or gyratory crushers.

The powdered body material is mixed with the required proportion of coal tar or pitch in mixing machines. The paste obtained is shaped by moulding or extrusion.

The green or unbaked electrodes are examined for such defects as splits, core carbon, distortion in shape, excess of binder, and blistered skin and approved ones are baked to convert high-resistance green electrodes into low-resistance products with the desired properties. A baking temperature of 1,100° is high enough to carbonize the binder. As the electrodes soften during baking, they are held in place by filling the interstices with finely ground petroleum coke. The loss during baking is c. 10% of the weight of the electrode.

For the manufacture of amorphous carbon electrodes, baking is carried out in electric or gas-fired furnaces at 1,250°. Baked electrodes are cooled gradually to prevent strains. Baking and cooling take several weeks. For the manufacture of graphite electrodes, the green electrodes are first baked in gas-fired furnaces and graphitized in electric resistance furnaces at 2,000–3,000°. Alternatively, the green electrodes are directly loaded into electric furnaces and baking and graphitizing operations are effected in one step.

After cooling, the electrodes are cleaned of adhering material and tested for ash, resistivity, apparent density, volatile matter, and tensile strength. Rejections are sent back into process. Cleaned electrodes after inspection are stored for despatch or are sent to the machining section for threading or tapping for continuous feeding in furnaces.

Table 20 gives the comparative properties of amorphous and graphitic carbon electrodes.

The conductance of graphite electrodes is four times that of amorphous carbon electrodes and for securing the same conductance a graphite electrode need have half the diameter of an amorphous carbon electrode. The use of graphite electrodes offers certain advantages: owing to the smallness of the size, they do not require heavy controlling mechanisms; transportation charges are low and, when broken, they can be easily replaced; graphite electrodes suffer no resistance loss at the joint and require no jointing compound; owing to their greater resistance to oxidation, the consumption is less than half of that of amorphous carbon electrodes. Some of the disadvantages are: they are more expensive (2–2.5 times that of amorphous carbon electrodes) and more fragile; owing to their higher heat conductivity the heat loss also is greater.

Amorphous carbon electrodes are used in the manufacture of ferro-alloys, for which purpose their low price more than counterbalances the

ELECTRICAL INDUSTRIES

TABLE 20—PROPERTIES OF AMORPHOUS AND GRAPHITIC CARBON ELECTRODES*

| | Acheson graphite | Amorphous carbon † | Gas-baked amorphous carbon | Large electro-thermal |
|--|-------------------------------|--------------------|----------------------------|-----------------------|
| Specific resistance, ohm/in. cube | 0.00032 | 0.00124 | 0.00161 | 0.00220 |
| Comparative section area for same voltage drop | 1 | 3.8 | 4.0 | 6.8 |
| Weight, lb./cu. ft. | 99.0 | 97.5 | 97.0 | 100.0 |
| Apparent density, g./cc. | 1.585 | 1.558 | 1.55 | 1.60 |
| Tensile strength, lb./sq. in. | | | | |
| lengthwise | 800-1,000 | 1,000-1,500 | 1,000-1,500 | .. |
| crosswise | 500-600 | 600-900 | 600-900 | .. |
| Temp. of oxidation in air, °C. | 640 | 500 | 500 | 500 |
| Mantell, 270 | Good electric baked electrode | | † Typical small electrode | |

advantages of garphite electrodes. In the manufacture of aluminium, only amorphous carbon electrodes are employed as due to the oxidation of the anode, electrode consumption is high. Graphite electrodes are used in electrolytic work for which low resistance and long life are important considerations; they are extensively used in the electrolytic production of chlorine and caustic soda, chlorination of gold ores, recovery of copper, nickel, and zinc, and production of hypochlorites.

A continuous type of electrode, which is made *in situ*—Soderberg electrode—has come into use in the manufacture of calcium carbide, ferro-alloys, and aluminium, and in the electric smelting of iron. It consists of a ~~sheet~~ metal casing into which a pasty mixture of the raw materials is tamped. The electrode is added as it is consumed by lengthening the sheet metal casing and filling up with fresh electrode paste. The paste is of the same composition as that used for furnace electrodes. The lower part of the electrode is baked by the waste heat from the furnace. As the baking is effected under pressure and proceeds vertically upwards, no pressing is required. Once the electrode is set up in the furnace it works continuously during the whole period of operation of the furnace. The finished electrode, which may be round or oval in cross-section, has the same apparent density, conductivity, and crushing strength as the electrode made by other processes. It has a low heat loss, good resistance to oxidation, and is free from breakages. It has found application in non-tilting ferro-alloy furnaces and tilting steel furnaces.

The Indian industry—Amorphous carbon and graphite electrodes are not produced in India at present.

Soderberg electrodes are being manufactured by the *Aluminium Corporation of India Ltd.*, Asansol, the *Indian Aluminium Co. Ltd.*, Alwaye (Travancore), and the *Mysore Iron & Steel Factory Ltd.*,

TABLE 21—COMPOSITION OF GREEN AND CALCINED COKE*

| | Green coke | Calcined coke |
|----------------------|------------|---------------|
| Moisture, % | 0.19 | 0.02 |
| Fixed carbon, % | 89.29 | 98.32 |
| Volatile matter, % | 9.88 | 0.32 |
| Ash, % | 0.64 | 1.34 |
| Fe, % | 0.07 | 0.06 |
| Si, % | 0.14 | 0.25 |
| Real density, g./cc. | 1.363 | 2.026 |

* Information from the *Indian Aluminium Co., Ltd.*

Bhadravati for use in the manufacture of aluminium and ferro-silicon. The raw materials used are calcined petroleum coke and soft pitch. Green petroleum coke is obtained from Digboi (Assam) (Table 21).

Soft pitch is obtained from *Shalimar Tar Products (1935) Ltd.*, Lodna and *Bararee Coke Co. Ltd.*, Kusunda (Dt. Manbhum, Bihar). Blended pitch used as binding material by the *Indian Aluminium Co. Ltd.*, Alwaye has the following analytical values: free carbon, 19.03; coking value, 49.3; ash, 0.345; Si, 0.03; and Fe, 0.03%; softening point, 34.5°. The fractional distillation values are as follows: 20-170°, nil; 170-230°, 0.36; 230-270°, 2.23; 270-360°, 13.70; and residue, 83.71%. The quantities of coke and pitch consumed per ton of aluminium are: petroleum coke, 0.52-0.55 ton; and pitch, 0.16-0.17 ton (Information from the *Indian Aluminium Co., Ltd.*).

Petroleum coke is calcined at about 1,200° in a Reed hammer furnace to drive away the volatile matter; it is then crushed, ground, and sieved to three grades: -3 + 20, -20 + 48, and -48. The proportions of different sizes in the charge are so adjusted that the paste mix, known technically as the Densest Mix, has the maximum density. The electrode paste is made up of 72% petroleum coke and 28% soft pitch. The ingredients are mixed at 135-150° in a mixer till a homogeneous paste is obtained. The paste is heated in a steam-jacketed container using steam

TABLE 22—ANNUAL PRODUCTION AND CONSUMPTION OF SODERBERG ELECTRODES
(Qty in tons)

| | <i>Aluminium Corporation of India*</i> | | <i>Indian Aluminium Company Ltd.†</i> | |
|------|--|-------------|---------------------------------------|-------------|
| | Production | Consumption | Production | Consumption |
| 1948 | 942.0 | 956.5 | 1,683.3 | 1,674.6 |
| 1949 | 849.0 | 847.0 | 1,675.7 | 1,593.0 |
| 1950 | 978.0 | 983.5 | 1,561.1 | 1,517.4 |
| 1951 | 1,060.0 | 1,051.0 | 1,357.4 | 1,345.1 |
| 1952 | 726.0 | 726.0 | 1,591.1 | 1,603.0 |

* Information from the *Aluminium Corporation of India, Ltd.*

† Information from the *Indian Aluminium Co., Ltd.*

at a pressure of 75 lb./sq. in. The paste is poured in the anode casing of the reduction furnace where, by the heat of the furnace the volatile matter in the pitch is driven away.

The specifications for Soderberg electrodes are as follows: resistivity, 70–80 ohms/meter/sq. mm.; compression strength, 200–250 kg./sq. cm.; apparent density, 1.4–1.6 g./cc.; and real density, 2.02 g./cc. The consumption of electrode per ton of aluminium produced is 0.58–0.62 ton.

Table 22 gives the production and consumption of Soderberg electrodes by the *Aluminium Corporation of India Ltd.* and the *Indian Aluminium Company Ltd.* It is estimated that the production of Soderberg electrodes in the *Mysore Iron & Steel Factory* for consumption in the ferro-silicon plant is about 600–700 tons per annum.

ARC LIGHT AND ILLUMINATION CARBONS

Arc carbon consists of an outer carbon shell and a core. The shell is made of lamp black or petroleum coke and a binder, rendered into a paste, extruded, and baked. The core may be separately made, inserted into the shell, and fixed by cementing, or alternatively, the core mixture may be extruded into the hole of the shell and baked.

The core is made from the same raw materials as the shell; retort carbon, lamp black, and graphite are often incorporated. The core contains a small amount of arc-supporting material, such as a potassium salt, and up to 75% of a flame material. The former provides a supply of ions to ensure a steady conducting path and the flame material supplies volatile matter in the arc stream for the production of radiations of the required wave lengths.

Various types of carbon rods are produced to meet the requirements of consumers. The spectrum composition of the radiation can be altered as desired by changing the ingredients in the core. Metals of the cerium group are used for 'sunshine' type of radiation, while iron, chromium, titanium,

and copper are used for ultra-violet radiation. Neutral cored carbons are used for low intensity arcs; the core is small and contains a small quantity of alkali salt; the gas column between the electrodes is faintly luminous and the light emanates from the incandescent tips of carbons, especially the tip of the positive, which is much brighter. In the flame arc, the principal source of radiation is the gas present in the gap between the tips of the electrodes; the core is much larger than that in low-intensity arc carbons. The core of the positive electrode in a high intensity arc contains metals of the cerium group; the arc is operated on direct current at high density (of the order of 100 amp./sq. cm.).

Illuminating carbons are often copper plated to increase their electrical conductivity. Both electrodes of the flame arc are plated; only the negative electrode of the high intensity arc is plated, but if the current range is below 100 amp. the positive electrode is also plated. During the operation, the plating melts and drops off.

Carbon arc lamps are used for the projection of light, specially in photography, motion pictures, and searchlights. An enclosed type of low intensity arc, on account of its high cyanogen-band emission in the near ultra-violet region, is particularly effective for blue printing. The flame arc with the characteristics of daylight is used in still and motion picture photography, both black-and-white and colour. The electrodes for this purpose are cored with rare earth metals. Flame arcs with electrodes cored with iron and other metals are used for the production of ultra-violet radiation.

Arc carbons are not produced in India at present. It is estimated by the Films Enquiry Committee that the value of carbons annually imported for use in cinematograph projectors is about Rs. 12 lakhs.

CARBON BRUSHES

Carbon brushes are employed for conducting current to and from revolving parts of electric machines. The principal types are power and rotary converter brushes, automotive generator and starter brushes, and aviation generator and starter brushes.

Carbon brushes are manufactured by processes somewhat similar to those employed in the manufacture of carbon electrodes.

The principal raw material used in the manufacture of brushes is petroleum coke. It is heated in calciners to give a non-abrasive carbon, called Electrographite. Other materials used are natural amorphous graphite, lamp black, and carbon black. Sometimes retort or gas carbon, which is hard and dense, is employed to give a cutting grain to the brush and make it slightly abrasive. Powders of metals, such as copper, zinc,

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lead, and tin, either alone or in mixture, are used in metal carbon or metal graphite brushes. Coal tar pitch and resins are employed as binding materials.

Coke and electrographite are ground together in a Raymond roller mill and mixed with the requisite amount of pitch in a steam-jacketed, bread type mixer. Metal and metal graphite mixes are prepared in a similar mixer, or in a tumbling barrel, or in a ball mill without balls. The mixed paste is cooled, ground, and remixed so that the mix may have the necessary grain size. It is then moulded or extruded to give blocks, plates, or rods and subsequently machined to give brushes required for various purposes.

The green shaped pieces are baked at a temperature of 1,000–1,300°. For this purpose they are placed in saggers with powdered calcined coke as packing material and heated in a furnace for varying periods—from 8 hr. to 4 weeks—depending on the size and type of material, the furnace, and the method of heating. Brush materials are made in 3 grades: high altitude, electrographite, and metal graphite. Baked and graphitized plates and brushes are tested for resistivity, density, scleroscope and monotron hardness, breaking strength, contact drop, and ash.

For making brushes, the plates are surfaced and cut into strips with the help of grinders and abrasive cutting wheels. The strips are cut into brush blanks and ground to size. The blanks are then bevelled and the radius ground into the commutator end of the brush on shaped abrasive wheels. Holes are then drilled into the blanks; holes for rivet or bolt connections are counter-bored. The holes are sometimes copper plated or coated with silver, tin, or cadmium for effective electrical contact. Terminals are soldered on brush shunts. A noteworthy development of the German carbon brush industry is the use of iron powder in place of copper powder for tamped connections (*FIAT Final Rep.* No. 115, 1945, 14).

On account of the phenomenal development in aviation, the demand for brushes required in aviation machinery has greatly increased. New problems in brush manufacture have arisen; due to low moisture and oxygen concentration of the atmosphere at high altitudes and also fall in pressure, the service life of the brush is reduced. Thus a brush with a life of 1,000 hr. at sea level gives a service of only a few hours at an altitude of 30,000 ft. Several impregnants have been discovered for imparting normal life to brushes required for service at high altitudes.

The Indian industry—Carbon brushes are not manufactured in India from indigenous raw materials. There are a few firms established in India producing brushes from imported stock. Messrs. Balmer Lawrie & Co., Ltd., Calcutta, Messrs. British India Electric Construction Co.

Ltd., Calcutta, Messrs. Beni Engineernig Works Ltd., Calcutta, and Messrs. Greaves Cotton & Crompton Parkinson, Ltd., Bombay are the principal producers of brushes for industrial motors and generators, traction motors, fan motors, train lighting equipment, automobile generators and starters, fractional h.p. motors, lift controller contacts, and brushes for electric supply station equipment, e.g. rotary converters, generators, and turbo-alternators. The average annual output of Messrs. Balmer Lawrie & Co. Ltd. is estimated at 250,000 brushes, that of Messrs. Greaves Cotton & Crompton Parkinson, Ltd. being estimated at 150,000.

Total production data of carbon brushes in India are not available. Aircraft brushes are not produced in India. The quantity and types of brushes produced are insufficient to meet the demands. As carbon brushes are not separately listed in the *Foreign Trade and Navigation Accounts of India*, no import figures are available.

BATTERY CARBONS

Battery carbons are small sized electrodes made by extrusion and moulding. They are used as positive poles in primary and dry cells. The entire requirements of battery carbons are met by imports. An idea of the total demand may be had from the following figures for dry cells:

TABLE 23—IMPORTS OF ELECTRIC CARBONS

| | Val. (lakh Rs.) |
|-----------------------|--------------------|
| 1934/35–1938/39 (av.) | 2.30 |
| 1939/40–1943/44 (av.) | 6.34 |
| 1944–45 | 6.46 |
| 1945–46 | 11.14 |
| 1946–47 | 7.78 |
| 1947–48 | 10.50 |
| 1948–49 | 20.15 |
| 1949–50 | 20.00 |
| 1950–51 | 34.85 |
| 1951–52 | 51.48 |
| 1952–53 | 22.26 |

TABLE 24—IMPORTS OF ELECTRIC CARBONS FROM U.K.
(Qty in numbers and val. in £)

| | Electric carbon, lighting | | Other types | |
|------|------------------------------|--------|-------------|--------|
| | Qty | Val. | Qty | Val. |
| 1946 | 64,408 | 2,786 | 266,417 | 10,620 |
| 1947 | 144,663 | 4,029 | 206,708 | 2,922 |
| 1948 | 788,745 | 14,910 | 232,240 | 4,070 |
| 1949 | 1,645,776 | 30,593 | 73,801 | 7,595 |
| 1950 | 2,533,232 | 39,681 | 67,905 | 14,204 |

* Tr. U.K.

TABLE 25—IMPORTS OF ELECTRIC CARBONS FROM U.S.A.*

| | Furnace and electro- lytic carbon | | Brushes and stock | | Carbons, lighting | |
|------|--------------------------------------|--------------|-------------------------|--------------|-------------------|--|
| | Qty (lb.) | Val. (\$) | Val. (\$) | Qty (nos) | Val. (\$) | |
| 1948 | 4,670,980 | 430,004 | 21,849 | 2,559,070 | 169,978 | |
| 1949 | 1,505,646 | 276,144 | 35,004 | 1,553,000 | 110,523 | |
| 1950 | 1,559,686 | 294,951 | 46,848 | 1,867,400 | 146,084 | |
| 1951 | 877,351 | 178,674 | 54,835 | 3,930,140 | 313,587 | |

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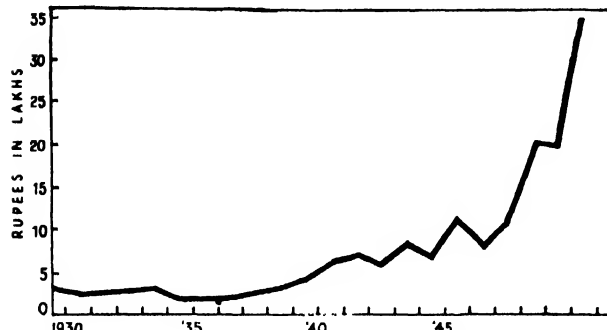


FIG. 30—IMPORTS OF ELECTRIC CARBONS INCLUDING FURNACE ELECTRODES

1948-49, 131.6 millions; 1949-50, 170.0 millions; and 1950-51, 147.5 millions.

Imports—The total imports of electric carbons, including furnace electrodes, are given in Table 23. U.K. and Germany were the principal suppliers up to 1937-38. In the quinquennium following this period, U.S.A. was the principal supplier, followed by U.K. Tables 24 and 25 give imports of electric carbons from U.K. and U.S.A.

Domestic appliances

Electric appliances used in households include personal and massage appliances, such as electric razors, curling irons, hair dryers, heating pads, and vibrators; labour saving equipment, such as vacuum cleaners and electric irons; food prepa-

ration equipment, such as mixers, fruit juice extractors, coffee mills, coffee percolators, toasters, and egg cookers; and heating appliances, such as immersion heaters, cooking ranges, hot plates, and radiation heaters.

Raw materials—The raw materials and components required in the manufacture of domestic appliances are resistance wires and strips, ceramic bases and wire holders, insulators, ferrous and non-ferrous castings, sheet metal pressings, bakelite or other moulded parts for terminal connections, and cloth, paper, and galvanized iron wire for lamp shades.

Heating elements should be resistant to corrosion and oxidation, should be able to operate at high temperatures without deterioration, and should not rust when exposed to moisture and air. They should have a high tensile strength and low coefficient of linear expansion. They are usually made of nickel-chromium or nickel-iron-chromium alloys—Kromore, Silichrome, Nichrome, and Calido. Their resistances as compared to that of copper (taken as 1) are: kromore, 55; silichrome, 65; nichrome, 66; and calido, 66. Table 26 gives the physical properties of heating elements; the properties of copper, iron, and nickel are included for comparison.

Heating elements are employed either in ribbon form or in wire form. Ribbon elements are employed in flat irons as they have a greater radiating surface and are not easily displaced from their positions. Either ribbon or coiled wire elements are used in electric toasters. Coiled wire may be mounted on mica or porcelain grids or housed in a protective tubing of copper or brass, the space between the coil and the tube being filled with magnesium oxide. Coiled wires are generally used in radiators, stoves, ranges, and immersion water heaters.

The refractory material used in domestic appliances should have adequate mechanical strength; it should not deteriorate and become brittle due to heating and cooling under service conditions; it should be capable of withstanding thermal shocks.

TABLE 26—PHYSICAL PROPERTIES OF HEATING ELEMENTS*

| | Ohms/circular mil. foot | Temp. coeff. at 750°F./°F. | Coeff. of linear expn. °F. | Standard working Temp. °F. | Tensile strength lb/sq. in. (annealed) | Sp. gr. |
|---------------|----------------------------|----------------------------------|----------------------------------|----------------------------------|---|---------|
| Copper | 10.37 | 0.002220 | 0.0000093 | .. | 35,000 | 8.94 |
| Iron (pure) | 54.00 | 0.003530 | 0.0000064 | .. | 60,000 | 7.80 |
| Nickel (pure) | 64.00 | 0.002220 | 0.0000076 | .. | 80,000 | 8.90 |
| Kromore | 567.60 | 0.000100 | .. | 2,000 | 80,000 | 8.90 |
| Silichrome | 655.00 | 0.000230 | .. | 1,800 | .. | 7.50 |
| Nichrome | 660.00 | 0.000095 | .. | 1,800 | 98,000 | 8.90 |
| Calido | 660.00 | 0.000090 | .. | 1,800 | .. | 8.15 |

* *Applied Electricity*, American Technical Society, 1945, 1, 180

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Insulations must be sound and non-inflammable; connections between elements and switches or terminals should not be made with soft solder.

Resistance wires used in the domestic appliances industry in India are wholly imported. Indigenous production of ceramic bases of the required quality is not adequate to meet the demands. A major part of it is imported and so are moulded parts for terminals. Insulators and ferrous and non-ferrous castings and sheet metal pressings are produced within the country.

Manufacture—ELECTRIC IRONS.—The different parts of an electric iron are: (1) sole plate; (2) heating element; (3) top casing of cast iron; and (4) hood to which the handle is attached. The heating element, either in ribbon or wire form, is mounted above the sole plate. If a ribbon element is used, it is wrapped on mica sheet; if the element is in wire form, it is wound into a spiral, encased in a protective metal tube or sheet, and packed in magnesia. An adjustable thermostatic arrangement is sometimes provided. Steam irons are similar to standard electric irons except that they contain a steam chamber and water reservoir. The heat from the heating element raises the temperature of the sole plate and also causes the water to boil so that steam is emitted from a vent in the sole plate.

ELECTRIC RADIATORS are employed for raising the temperature of the atmosphere in rooms during winter. Numerous types of radiators are in use. One or more lengths of resistance wires are employed for producing the heat. In some, a reflector is placed behind the hot element for radiating the heat in a broad beam. In others, the element is sandwiched between glass panels, the entire assembly constituting the radiator. In yet others, fans are provided to draw cold air past the heating element and to blow the warm air into the room.

The most common type of electric radiator consists of a coil of nichrome wire wound on a cylindrical or conical insulator and fixed at the centre of a reflector bowl. In some radiators, the heating unit is screwed to the reflector. In the vertical type of radiator, the element is mounted in front of the reflector, which is a half cylinder sliced lengthwise. The convection electric heater is a covered radiator. Two elements wound on cylindrical insulators are fixed inside the cover. When the current is switched on, the air around the elements gets heated; the heated air rises and cold air is drawn in; the air in the room is warmed as a result of the convection current produced thereby. Electric radiators are tested for insulation resistance, dielectric strength, earthing, performance, and fire risk. Only the bowl type of radiators are produced in India.

The **IMMERSION HEATER** is a portable appliance designed for heating liquids. It consists of a sheathed heating element, the terminals of which are mounted in moulded insulating blocks, and a handle. The metal casing is a thick copper tube electroplated to resist corrosion. The heating element, which is a coiled nichrome wire, is placed inside the tubing centrally and held in position by magnesium oxide packing. A rigid spaced bushing or filling is provided at the point where the element emerges from the sheath making the assembly water-tight. The handle is made from an insulating, fire- and moisture-resisting material. A hook is attached to heaters with a rating exceeding 7.5 amp. for supporting the appliance to the side of the vessel. Immersion heaters are tested for insulation resistance, dielectric strength, earthing, loading, and over-heating.

BOILING PLATES are used as stoves or ovens for heating water or other liquids. A coiled resistance wire is supported on a refractory base and fixed in a frame. The plate surface may be flat or concave. A metal grille or guard is provided at the top to prevent the heating vessel from coming into direct contact with the heating element. Suitable non-ignitable materials are used for insulating electrical connections. Boiling plates are tested for insulation resistance, dielectric strength, earthing, table temperature, performance, life, and thermal and chemical shock resistance.

ELECTRIC KETTLES are portable vessels with immersion or clamp-on type heating elements fixed at the bottom. The handle is made of non-conducting, heat insulating material. The heating element is provided with terminal pins, screws, or studs for connecting it to the power supply. Safety devices are sometimes fitted to

TABLE 27—IMPORTS OF FLAT IRONS AND HEATING EQUIPMENT FROM U.K.*

| | Cooking app. & heating elements | Heating app. & heating elements | Other accessories of cooking & heating app. | Electric flat irons | |
|------|---------------------------------|---------------------------------|---|---------------------|-------------|
| | Val. (£) | Val. (£) | Val. (£) | Qty (no.) | Val. (£) |
| 1942 | 575 | 2,899 | .. | .. | .. |
| 1943 | 416 | 2,511 | .. | .. | .. |
| 1944 | 303 | 2,526 | .. | .. | .. |
| 1945 | 3,242 | 7,376 | .. | .. | .. |
| 1946 | 35,675 | 63,962 | 2,260 | .. | .. |
| 1947 | 80,028 | 132,074 | 7,348 | .. | .. |
| 1948 | 42,081 | 54,586 | 4,122 | 39,021 | 31,512 |
| 1949 | 46,005 | 53,672 | .. | 41,141 | 27,727 |
| 1950 | 17,276 | 21,189 | .. | 46,411 | 33,162 |

* Tr. U.K.

TABLE 28—IMPORTS OF DOMESTIC ELECTRIC APPLIANCES FROM U.S.A.*
(Qty in numbers and val. in \$)

| | 1948 | | 1949 | | 1950 | | 1951 | |
|--|-------|--------|-------|--------|------|-------|------|-------|
| | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. |
| Vacuum cleaners, domestic | 1,215 | 17,545 | 24 | 425 | .. | .. | .. | .. |
| Mixers and blenders, household | .. | .. | 924 | 11,593 | 109 | 2,985 | 506 | 5,489 |
| Razors | .. | .. | .. | .. | 16 | 203 | .. | .. |
| Household appliances, other types | .. | .. | .. | 2,968 | .. | 1,243 | .. | 1,424 |
| Flat iron | 4,221 | 15,804 | .. | .. | 41 | 613 | .. | .. |
| Cooking ranges, domestic | 20 | 3,036 | 14 | 2,094 | .. | .. | .. | .. |
| Percol toast waf. iron | 1,156 | 5,024 | 1,081 | 13,178 | .. | .. | .. | .. |
| Cooking apparatus, household, other types | .. | .. | .. | 16,181 | .. | 3,335 | .. | .. |

* U. S. Exports of Domestic and Foreign Merchandise

protect kettles against boiling dry. In one type, the heating element is disconnected from the supply circuit until it is manually reset; in another type, a thermostatic device is employed which switches off the current when the temperature reaches a particular limit. Electric kettles are subjected to tests for insulation resistance, dielectric strength, earthing, loading, temperature, capacity, performance, and life.

The manufacture of domestic appliances is carried out by scores of small scale establishments located in Bombay, Calcutta, Madras, Delhi, and other urban areas. Large scale production has been undertaken by a few concerns, e.g. *India Electric Works Ltd.*, Calcutta.

Domestic electric appliances manufactured in India are required to conform to the Indian Standard Specification No. IS: 302-1951.

Production and Trade—Statistics of production of domestic electric appliances are not available. The Panel on Electrical Machinery and Equipment estimated the value of annual requirements during 1945-1950 at Rs. 30 lakhs. (*Panel Rep., Development of Electrical Industries, 1947, 36*).

Imports—Table 27 gives imports of flat irons, cooking and heating apparatus, and heating elements therefor from U.K. Table 28 gives the imports from U.S.A.

Fans

The manufacture of electric fans in India is at present mainly confined to propeller-type ceiling fans, table fans, railway carriage fans, and pedestal fans.

An electric fan is essentially a fractional h.p. motor to the rotor of which are fixed suitably shaped blades. D.C. ceiling and table fans are made from series-wound motors in which the field coils are in series with the armature, the current flowing through both. Blades are fixed to the armature spindle.

Shaded-pole single-phase motors are commonly

used for driving both a.c. ceiling and table fans. They are comparatively less expensive than other types and the speed of rotation can be controlled by varying the voltage. Capacitor-run motors are also used in driving a.c. ceiling fans. In comparison with the shaded-pole type they have higher power factor and greater efficiency. The speed is regulated by controlling the voltage. Blades are directly attached to the rotor which is the external component in a.c. ceiling fans. The stator is built on to a stationary spindle which hangs by a down rod from the ceiling. In a.c. table fans the blades are fixed to the rotor spindle.

The *India Electric Works Ltd.*, Calcutta, which had its beginning in 1922, was the first fan factory to be established in India. The success achieved by the company provided encouragement for starting other fan manufacturing concerns. By 1939, there were seven producers with a total annual capacity of 40,000 fans. World War II gave

TABLE 29—STATEWISE DISTRIBUTION OF FAN FACTORIES

| | No. | Annual installed capacity (no.) |
|----------------|-----|---------------------------------|
| West Bengal | 10 | 214,600 |
| Bombay | 3 | 50,000 |
| Delhi | 4 | 26,500 |
| Punjab & PEPSU | 1 | 2,500 |
| | 18 | 293,600 |

TABLE 30—ANNUAL INSTALLED CAPACITY OF FAN FACTORIES

| | No. |
|------|---------|
| 1946 | 138,000 |
| 1947 | 250,000 |
| 1948 | 250,000 |
| 1949 | 301,600 |
| 1950 | 278,400 |
| 1951 | 276,500 |
| 1952 | 293,600 |

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a fillip to the industry. The demand for fans increased and imports declined. A large number of new factories were set up, mainly in Calcutta, Bombay, Delhi, and Lahore. At one time as many as 75 concerns were known to be manufacturing fans; but many of them had to be closed down after the war. In 1949 there were 26 factories producing fans, of which 6 (combined rated capacity, 21,600 fans) were taken off the active list in 1950 and production was confined to 20 well-organized factories; two more firms were subsequently removed from the list. At present there are 18 firms which may be considered as established manufacturers of fans, their total installed capacity being 293,600 fans per year on the basis of single shift operation for 300 days

in a year. The principal manufacturers are: *India Electric Works Ltd.*, Calcutta, *Calcutta Electrical Manufacturing Co. Ltd.*, Calcutta, *Crompton Parkinson (Works) Ltd.*, Bombay, *General Electric Co. of India, Ltd.*, Calcutta, *Jay Engineering Works Ltd.*, Calcutta, *Matchwel Electricals (India) Ltd.*, Delhi, *Engineering Works of India Ltd.*, Calcutta, and *G.T.R. Co. Ltd.*, Calcutta. Table 29 gives the Statewise distribution of factories. Table 30 gives the total annual installed capacity.

Taking into account the rated capacity of factories now off the list and of a few others operating in different parts of the country, the present rated capacity of the industry has been estimated at about 300,000 fans. The total capital invested

TABLE 31—IMPORTED RAW MATERIALS REQUIRED PER 100 FANS*

| | Ceiling fans (60 in./56 in.) | | Table fans (16 in.) | |
|--------------------------------------|------------------------------|-------------|---------------------|-------------|
| | a.c. | d.c. | a.c. | d.c. |
| Winding wires (super enamel) | 650 lb. | 320 lb. | 90 lb. | 128 lb. |
| Flexible and R.B. cords : | | | | |
| Flexible cord | 100 ft. | 25 ft. | 76 ft. | 390 ft. |
| R B cord, 14/10076 | .. | .. | 1,000 ft. | 1,000 ft. |
| Single core, unbraided, flexible | .. | 166 yd. | .. | .. |
| Insulating materials : | | | | |
| Ebonite rods | 2½ ft. | 2½ ft. | 3½ ft. | 3½ ft. |
| Empire cloth | 50 ft. | 100 ft. | .. | 15 ft. |
| Empire tape, 3½ in. | .. | .. | 1,584 yd. | 432 yd. |
| Tube, 2 mm. | 210 ft. | 450 ft. | 150 ft. | 30 ft. |
| Egyptian cotton tape | 2,160 yd. | 189 yd. | .. | .. |
| Fibre sheet— | | | | |
| 1/16 in. | 1½ lb. | 1½ lb. | ½ lb. | 1 lb. |
| 1/32 in. | .. | 4½ lb. | .. | .. |
| Leatheroid | .. | 20 lb. | 2½ lb. | 9½ lb. |
| Bakelite powder | 26 lb. | 26 lb. | 7 lb. | 7 lb. |
| Grease, high melting point | 2 lb. | 2 lb. | 2 lb. | 2 lb. |
| Non-ferrous brass : | | | | |
| Brass brand, cold rolled, | | | | |
| 20 in./7½ in. | .. | .. | 112 lb. | 112 lb. |
| Brass rod, ½ in. to ¾ in. | 3 lb. | 2½ lb. | 16 lb. | 17 lb. |
| Hex brass, 5/16 in. | 16 lb. | 16 lb. | ½ lb. | ½ lb. |
| Brass wire No. 9 | .. | .. | 56 lb. | 56 lb. |
| Brass pipe | .. | .. | .. | 4 lb. |
| Hard drawn copper strips | .. | .. | .. | 15 lb. |
| Red steam pipes | 100 ft. | 100 ft. | .. | .. |
| Ball-bearings | 200 units | 200 units | 200 units | 200 units |
| Carbon brushes, 1/6 mm. | .. | .. | .. | .. |
| Condenser, 2 mfd. | .. | 100 units | .. | .. |
| Non-ceramic paints | 12 gal. | 12 gal. | 3 gal. | 3 gal. |
| Non-ceramic thinner | 9 gal. | 9 gal. | 3 gal. | 3 gal. |
| Water-proof paper | 90 sheets | 90 sheets | 60 sheets | 60 sheets |
| Gold powder | 2 lb. | 2 lb. | 3 lb. | 3 lb. |
| Phosphor bronze wire, No. 26 | .. | .. | .. | ½ lb. |
| Tinned sheets, 24 SWG, 20 in./28 in. | 2 lb. | 2 lb. | .. | .. |
| Screws : | | | | |
| C.S.K. iron, Ch. hd iron, etc. | 3,500 units | 3,700 units | 800 units | 1,200 units |
| Sq. hd iron | 300 do. | 300 do. | .. | .. |
| Round hd iron | .. | 400 do. | 1,800 do. | 1,400 do. |
| C.S.K. brass | 200 do. | 200 do. | .. | .. |
| Round hd brass | 800 do. | 800 do. | 200 do. | 400 do. |
| Split pins | 200 do. | 200 do. | .. | .. |

* Information from *Fan Makers' Association of India*

TABLE 32—ANNUAL REQUIREMENTS OF IMPORTED RAW MATERIALS FOR 200,000 FANS*

| | Qty |
|--|---------------|
| Carbon brushes | 200,000 units |
| Special paints | 60,000 gal. |
| Ball bearings | 366,000 units |
| Steel pipe for down rods (including hoop iron, tin sheet, bright wire M.S., bolts, nuts, & washers) | 200 tons |
| Winding wires and insulating materials: | |
| Insulating copper winding wires (22-40 S.W.G.), double silk covered, enamelled, enamelled single rayon, etc. | 360 tons |
| Fibre sheets, leatheroid insulating beads, black insulating tapes, etc. | 60 tons |
| Empire cloth | 30,000 yd. |
| Empire tape | 12,000 yd. |
| Empire tube | 400,000 yd. |
| Bakelite moulding powder | 40 tons |
| Non-ferrous rods, tubes, sheets, and wires | 300 tons |
| Condensers | 300,000 units |
| Electroplating chemicals | 150 cwt. |

* Information from *Fan Makers' Association of India*

in the 18 factories has been estimated at Rs. 2 crores and the labour employed at 7,500.

Raw materials—The principal raw materials used in the manufacture of fans are cast iron, mild steel (M.S.), silicon steel, aluminium and brass sheets, winding wires, electrolytic copper rods, nichrome resistance wire, ball bearings, condensers, insulating materials, and pipes for down rods. Other materials required are shellac varnish for insulation, paints, carbon brushes, plastic moulding powders, porcelain parts, and non-ferrous sections.

Cast iron, mild steel and silicon steel sheets are available in the country. Mild steel black sheet (24-36 S.W.G.) is required for d.c. armature. Silicon steel sheets are manufactured by *Tata Iron & Steel Co. Ltd.*, Jamshedpur. They are tested, stamped, and supplied to fan manufacturers by *Sankey Electrical Stampings Ltd.*, Bombay. Steel pipes for down rods are imported.

Blades made from aluminium sheets (16-18 S.W.G.) have largely replaced steel blades for ceiling fans. Aluminium sheets of the required specifications are produced in the country in limited quantities. Blades for table fans are made of cold rolled brass sheets which are locally available. Blades for railway carriage fans are made from M.S. sheets.

Enamelled wire (23-38 S.W.G.) is employed for coils. Single-cotton-covered (S.C.C.) and double-cotton-covered (D.C.C.) copper wires are also used. A major part of the wire required by the fan industry is imported, domestic production

being limited. Nichrome resistance wire (34-38 S.W.G.) is also imported.

Insulating materials used in the industry are red fibre sheet (1/16 in. thick), leatheroid (7-19 mils), empire cloth (7 mils), empire tube, empire tape, presspahn paper, ebonite rod, Egyptian cotton tape, and mica. With the exception of the last two, other items are imported. Empire cloth is manufactured in limited quantities by *India Electric Works Ltd.*, Calcutta. Bakelite is imported in the form of powder or sheet. Shellac varnishes for insulating coils are obtainable locally.

Most manufacturers use ball bearings for rotating parts. The manufacture of ball bearings has been recently undertaken at Jaipur; the bulk of the requirements, however, is imported. Carbon brushes, condensers, paints (synthetic resin lacquers, thinners, nitrocellulose paints, zinc white, black and white enamel), porcelain parts, and non-ferrous sections, such as rods, wires, pipes, and screws, are mostly imported.

Table 31 gives the quantities of imported raw materials used in the manufacture of 100 fans of different types. Table 32 gives the annual requirements of some imported raw materials, based on an estimated production of 200,000 fans.

Manufacture—Series-wound, fractional h.p. motors are used for d.c. fans. Single-phase, shaded-pole, fractional h.p. motors are mostly



Crompton Parkinson (Works) Ltd., Bombay

FIG. 31—WINDING OF ARMATURE AND FIELD COILS

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used for a.c. fans. Capacitor-type motors are also used to a limited extent for a.c. ceiling fans.

Cast iron parts, such as top and bottom covers, yoke (for d.c. fans), blades, holders, canopy, regulator casing, lock nut (for a.c. fans) required for ceiling fans, and front and back covers and stands for table fans, are fabricated in the ferrous foundry. Ringer and fly nuts (brass), grease cups (aluminium), and short circuiting rings for a.c. rotors (copper) are produced in the non-ferrous foundry. The yoke for d.c. ceiling fans is cast with 4 pole pieces, that for d.c. table fans, with 2 pole pieces projecting inwards towards the armature; they are made integral with the yoke at the time of casting. In some d.c. ceiling fans, the pole pieces are separate from the yoke; they are built up of iron laminations and bolted to the yoke. The inner surface of the pole is bored to take the armature. The edges of the yoke are turned on lathes for fitting the end plates which are also machined for fitting and housing the ball bearings. Table fan end covers are drilled. Mild steel spindles are forged and the top side threaded for hanging.

CORE CONSTRUCTION—For the construction of armature cores for d.c. ceiling and table fans, mild steel sheets are blanked into circles and notches for armature coils punched in a single operation.

The punchings are coated with shellac varnish and, when dry, assembled in a jig, riveted, and the spindle inserted by a hydraulic press. Two fibre board discs similar to the punchings are fixed to the two sides of the armature core. The core is then inserted between the two end plates and turned to give a uniform air gap.

In the case of a.c. fans, both stator and rotor cores are made from silicon steel stampings. The sheets are sheared, blanked, and punched into rotor and stator laminations. The stator in ceiling fans and the rotor in table fans are provided with ventilation holes. Laminations are subsequently notched. Punchings for shaded-pole motors are of 'salient pole' construction. Many fan manufacturers obtain stampings in a notched condition from *Sankey Electrical Stampings Ltd.*, Bombay.

Stator punchings for a.c. ceiling fans are assembled in a jig, pressed, riveted, and fixed to a spindle. The outside of the assembly is machined to give a uniform air gap. The stator core of a.c. table fans, which forms the outer part, is constructed similarly. The core is fitted inside a cast iron yoke and the inside ground.

Rotor punchings for a.c. table and ceiling fans are arranged one above the other, pressed, fitted with copper end plates, and riveted. The punchings are so assembled that the coil slots are



FIG. 32—A.C. CEILING FAN ASSEMBLY LINE

India Electric Works Ltd., Calcutta



D.C. FAN ASSEMBLY LINE

Messrs. India Electric Works Ltd., Calcutta



FIG. 33—FAN TESTING

India Electric Works Ltd., Calcutta

skewed. The copper end plates are provided with the same number of holes as the number of slots in the core. Round copper rods are forced through the holes in the end plates so that they pass through oblique slots. The ends are then soldered. The inside surface of the rotor core is ground, if the rotor is required for ceiling fans, and ends cut in a lathe for fitting the covers and the outer surface is given a finish. If the rotor is required for use in a.c. table fans, the outside is machined and finished. A.C. ceiling fans are wound with 7 to 13 pairs of poles depending on the blade sweep of the fan. A.C. table fans are made with 4 poles.

COILS—Armature coils for d.c. fans are hand-wound. Prior to winding, a strip of empire cloth is inserted in the slot followed by a strip of leatheroid. Each slot carries two coil sides between which is placed a piece of empire cloth. Similarly, empire cloth is placed wherever coil ends cross each other. The ends of the insulation are folded after winding and a wedge of fibre inserted in each slot to prevent coils from coming out under the influence of the centrifugal force at the time of rotating.

Field coils for d.c. fans and stator coils for a.c.

fans are former-wound; field coils are completely taped, heated to expel moisture, dipped in insulating varnish, and baked in a hot chamber. Prepared field coils are inserted over the pole pieces, one coil on each pole. A.C. stator coils are taped at the ends and inserted in the stator core with suitable insulating materials. Closed shading bands made of copper are inserted over shaded poles; one side of the loop is embedded in the narrow slot coil in the pole, the other lying against the outside of the pole.

After the coils are inserted, the armature in d.c. fans or the stator in a.c. fans is bound with tape or strings. The completed core is again dipped in varnish, dried, and baked.

BLADES—Aluminium, brass, or steel sheets are cut to size, holes punched for the shank, and pressed in a die to give the proper curvature. Blades for ceiling fans are painted with aluminium paint.

COMMUTATOR—Hard drawn copper strips are cut into segments and assembled on a socket with interposed mica plates.

ASSEMBLY—In the case of d.c. ceiling fans, the commutator is inserted on the spindle and the free



Indha Electric Works Ltd., Calcutta

FIG. 34—FAN PAINTING SHOP

ends of the armature coils are soldered to appropriate commutator segments and the completed armature placed centrally inside the stator. Carbon brushes are fitted and the field and armature coils serially connected through the brushes. End plates and bearings are then fixed. In the case of d.c. table fans, the armature along with the commutator is inserted into the body of the fan and the

end cover fixed. The blades are attached and the guard mounted. Table fans are generally provided with 4 blades.

In a.c. ceiling fans, the stator is inserted in the rotor and end plates and bearings fixed. A.C. table fans are assembled in the same way as d.c. table fans.

The completed fan is tested for running temperature, wattage, r.p.m., resistance, air displacement, and general service value. They are spray painted and given a line decoration by hand.

The types of fans manufactured in India are d.c. and a.c. ceiling fans, table fans (fixed and oscillating), cabin fans (fixed and tilting), pedestal fans, and railway carriage fans. D.C. and a.c. ceiling fans are made with 24, 36, 48, 56, 60, 72, and 85 in. sweeps. Table fans are generally made with 12, 14, and 16 in. sweeps. All these are made for operation on 220/250 volts. Table 33 gives the characteristics of fans produced in India.

Production and Trade—Prior to World War II, the production of fans in India was about 30,000 ceiling fans and 5,000 table fans. Table 34 gives

TABLE 33—CHARACTERISTICS OF FANS

| Trade name | Type | Sweep (in.) | Watts at full speed | r.p.m. | Air displacement (cu. ft./min.) |
|------------|-------------------|-------------|---------------------|--------|---------------------------------|
| India | d.c. ceiling | 60 | 44 | 225 | 13,815 |
| Rohtas | do. | 56 | 48 | 215 | 12,060 |
| Bharat | a.c. ceiling | 60 | 62 | 207 | 13,200 |
| Ranjit | do. | 60 | 85 | 195 | 12,700 |
| Tara | d.c. table, fixed | 16 | 49 | 1,250 | 2,600 |
| Tara | a.c. table fixed | 16 | 54 | 1,250 | 2,300 |

the production of fans during the war. Table 35 gives the production of electric fans in recent years.

The pre-war demand for electric domestic fans was about 60,000-80,000 per annum. The present overall annual requirements have been estimated by the Tariff Board at 140,000-150,000 ceiling fans, 50,000-60,000 table fans, and 12,000 railway carriage fans. There is also a demand for pedestal fans. The total annual capacity of the Indian fan industry is expected to increase to

TABLE 34—PRODUCTION OF CEILING AND TABLE FANS*

| | Ceiling fans (no.) | Table fans (no.) |
|------|-----------------------|---------------------|
| 1940 | 38,000 | 6,800 |
| 1941 | 47,800 | 9,600 |
| 1942 | 38,400 | 11,000 |
| 1943 | 41,200 | 10,000 |

* Thomas, Rep. Metallurgical and Engineering Industries, 1944, 61

TABLE 35—PRODUCTION OF ELECTRIC FANS

| | Qty (no.) |
|------|--------------|
| 1946 | 110,433 |
| 1947 | 128,517 |
| 1948 | 158,753 |
| 1949 | 170,843 |
| 1950 | 199,739 |
| 1951 | 212,495 |
| 1952 | 195,400 |

TABLE 36—IMPORTS OF ELECTRIC FANS

| | Val. (Rs.) |
|-----------------------|---------------|
| 1934/35-1938/39 (av.) | 29,80,355 |
| 1939/40-1943/44 (av.) | 12,57,157 |
| 1944-45 | 1,92,973 |
| 1945-46 | 86,474 |
| 1946-47 | 18,96,258 |
| 1947-48 | 26,15,815 |
| 1948-49 | 2,12,100 |
| 1949-50 | 6,84,207 |
| 1950-51 | 3,23,390 |
| 1951-52 | 5,51,420 |
| 1952-53 | 4,46,371 |

TABLE 37—IMPORTS OF ELECTRIC FANS FROM U.K.*
(Qty in numbers and val. in £)

| | Qty | | | Val. | | |
|------------------|-------|-------|-------|--------|--------|--------|
| | 1948 | 1949 | 1950 | 1948 | 1949 | 1950 |
| Desk and ceiling | 3,122 | 3,712 | 1,415 | 14,787 | 20,088 | 11,674 |
| Other types | 5,454 | 4,550 | 3,699 | 71,740 | 61,452 | 64,302 |
| Fan parts(cwt.) | 560 | 727 | 905 | 16,421 | 20,586 | 24,232 |

* Tr. U.K.

TABLE 38—LANDED COSTS AND FAIR SELLING PRICES
(Val. in Rs. as. ps.)

| | Ceiling fan, 56 in. sweep, with regulator | | Table fan, 16 in. sweep, with regulator | |
|--|---|----------|---|----------|
| | a.c. | d.c. | a.c. | d.c. |
| C.i.f. price (G.E.C. fan) | 205- 0-0 | 222- 0-0 | 77- 0-0 | 96- 0-0 |
| Landed cost with duty | 259- 0-0 | 280- 8-0 | 98- 0-0 | 122- 0-0 |
| Fair selling price of indigenous fans (a) | 141- 3-6 | 145-13-0 | 101- 0-2 | 107-15-4 |
| (b) | 139-13-0 | 148- 1-1 | 77-13-9 | 77-10-9 |
| (c) | 124-11-8 | .. | .. | .. |

(a), (b), and (c) refer to fans manufactured by 3 firms

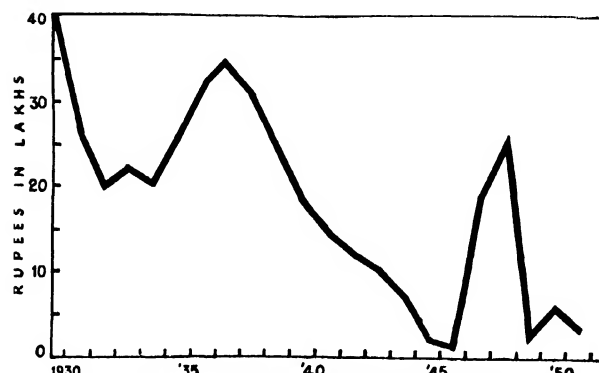


FIG. 35—IMPORTS OF ELECTRIC FANS

about 360,000 fans by 1955-56 with the implementation of the project of Messrs. Matchwel Electricals (India) Ltd., Delhi to manufacture railway carriage and table fans in their factory at Poona.

Imports—Table 36 gives imports of electric fans and parts into India. The shares of various countries in imports during the quinquennium ending 1938-39 were: U.K., 60.9; Italy, 16.9; Germany, 11.3; Japan, 5.3; and U.S.A., 4.8%. During the quinquennium ending 1943, U.K. supplied the major requirements (67.7%). The shares of U.K. in imports during 1947-48 and 1949-50 were 81.1 and 37.2% respectively. Imports of fans are under control since 1949. Table 37 gives the imports of fans from U.K. Table 38 gives the landed costs of imported fans and the fair selling prices of comparable indigenous fans as given by the Tariff Board.

Exports—Electric fans manufactured in India are being exported, in recent years, to Pakistan, Burma, Ceylon, Siam, Malaya, and Indonesia.

Fittings

Various items of equipment used for the secondary distribution and utilization of electricity, such as switches, wall plugs and sockets,

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lamp holders, adapters, and conduit pipes, are included under 'Electrical fittings'.

BAKELITE FITTINGS

There are about 80 producers of plastic products in India, many of them producing electrical fittings. The chief producers are: *Kay Engineering Co.*, Kapurthala, *Universal Plastic Products*, Bombay, *Swadeshi Industries Ltd.*, Calcutta, *India Moulding Co.*, Calcutta, *Kersons Manufacturing Co. of India Ltd.*, Bombay, *Plastic Manufacturers Ltd.*, Calcutta, *Hindusthan Plastics Ltd.*, Bombay, *Oriental Plastics Corporation*, Bombay, *Plastic Products Ltd.*, Kanpur, *Dominion Plastic Industries*, Bombay, *Government Electric Factory*, Bangalore, and *Electrical and Allied Industries (Travancore) Ltd.*, Kundara.

Raw materials—Phenol formaldehyde and phenol-furfuraldehyde moulding powders, steel

wire, brass rods, and porcelain insulators are the principal raw materials required in the manufacture of fittings. Moulding powders, such as Bakelite, Durez, Nestorite, and Moulderite, are imported. Other raw materials are available in the country in sufficient quantities.

Table 39 gives the properties of phenol-formaldehyde moulding powders of electrical grade.

Manufacture—Mouldings and brass parts are separately manufactured and assembled into various fittings. The moulding powder is preheated to 150–200°F. and moulded in a die press at c. 100 tons/sq. in., the mould being maintained at 150–180°. At the end of the curing period, the mould is opened and the moulded articles taken out.

Brass inserts are made from sheets, rods, and wires by punching, drilling, screw-cutting, and tapping. A few of the factories purchase the components and fix them into moulding parts by filing and drilling.

Secondary distribution and wiring devices are of diverse types and include the following: switches (flush tumbler, surface rotary, through-cord pendant and surface pull, safety, knife), fuse cut-outs with or without switches, lamp sockets and holders (screw socket, bayonet socket, and bipost socket bodies, lumline and fluorescent lamp holders, lamp holder socket caps), fuses (high voltage power, cartridge, plug, aerial, miniature fuses, radio and automotive), fuse links, ceiling roses, wall plugs, and push buttons. The tumbler switch, for example, contains four parts: base, cover, knob, and slider. The four parts are separately moulded. Brass parts, such as switch bridge, knob clip, contact fork, contact springs, pillars, and screws are turned out from brass rods and wires. The knob clip and contact fork are fixed to the two ends of the slider by brass wires. The knob is attached along with the bridge to the other end of the knob clip by a brass pin. A steel wire spring is then attached to the middle of the contact fork and fixed to the base by means of 2 screws. The two brass pillars are fixed to the base with brass springs and the pillars are fitted with screws for fixing the wires. After all the brass parts are fixed, the cover is screwed on to the base.

Production and Trade—The fittings manufactured in India are tumbler switches, ceiling roses, wall plugs and sockets, joint and fuse cut-outs, lamp holders (bracket, batten, and pendant types), lamp adapters, and push button switches. The quality of fittings manufactured from imported moulding powder is quite satisfactory. Table 40 gives the production of electrical fittings in India during 1943.

The total production of electrical fittings of all kinds during 1947–48 was about 16,000 gross.

TABLE 39—PROPERTIES OF PHENOLIC MOULDING POWDERS (ELECTRICAL GRADE)*

| | |
|---|------------------------------------|
| Specific gravity | 1.37–1.95 |
| Specific volume, cu in./lb. | 20.2–14.3 |
| Tensile strength, lb./sq. in. | 3,900–7,000 |
| Elongation at failure, % | 0.13–0.50 |
| Flexural strength, lb./sq. in. | 8,000–12,000 |
| Compressive strength, lb./sq. in. | 15,000–25,000 |
| Impact strength, Izod, ft. lb./in. notch | 0.30–0.38 |
| Modulus of elasticity, tension, lb./sq. in. | 30–40 × 10 ⁵ |
| Rockwell hardness | M99–M110 |
| Volume resistivity, ohm-cm. | 10 ¹² –10 ¹⁴ |
| Dielectric strength, v/mil, short time, 25° | 300–460 |
| step by step | 250–400 |
| step by step, 100° | 100–150 |
| Dielectric constant, 60c | 4.7–7.5 |
| 10°c | 4.4–7.0 |
| 10°c | 4.2–5.2 |
| Power factor, 60c | 0.01–0.06 |
| 10°c | 0.007–0.05 |
| 10°c | 0.005–0.04 |
| Loss factor, 60c | 0.05–0.45 |
| 10°c | 0.03–0.35 |
| 10°c | 0.02–0.21 |
| Thermal conductivity, cal./sq. cm./sec./°C/cm. | 10–14 × 10 ⁻⁴ |
| Thermal coefficient of linear expansion, max./°C. | 1.8–1.9 × 10 ⁻⁵ |
| Heat-distortion temperature, 264 lb./sq. in. | 110–177° |
| Flammability | Self extinguishing |
| Heat resistance, continuous | 121–149° |
| Water absorption, % | 0.01–0.10 |
| Compression ratio (bulk factor) | 2.1–2.7 |
| Temperature, compression | 149–166° |
| Pressure (lb./sq. in.) compression | 2,000–6,000 |

* Schack, 335

The total demand for plastic articles, including electrical accessories, is estimated at 1,000 tons. The Electrical Machinery and Equipment Panel fixed the target of production of electrical fittings at the value of Rs. 40 lakhs per annum (Indian Tariff Bd, Rep. *Plastic Industry*, 1949, 50, 16).

Table 41 gives the imports of electrical accessories and fittings into India. U.K. is the principal supplier of fittings.

TABLE 40—PRODUCTION OF BAKELITE FITTINGS IN 1943*

| | Qty (no. in dozen) |
|---|-----------------------|
| Ceiling roses, 2 plates, 5 amp. | 50,000 |
| Plugs, 2 pins, 5 amp. | 18,000 |
| Sockets, 2 pins, 5 amp. | 18,000 |
| Cut-outs, 5 amp. | 72,000 |
| Lampholders, bayonet cap, cord grip | 24,000 |
| Tumbler switches, surface pull, one way, 5 amp. | 48,000 |
| Tumbler switches, surface pull, one way with incorporated fuses | 4,800 |
| Switch plug combination, 5 amp. | 1,000 |

Thomas, Rep. *Metallurgical and Engineering Industries*, 1944, 64

TABLE 41—IMPORTS OF ELECTRICAL LIGHTING ACCESSORIES AND FITTINGS (INCLUDING SWITCHES)

| | Val. (Rs.) |
|-----------------------|---------------|
| 1934/35-1938/39 (av.) | 7,15,563 |
| 1939/40-1943/44 (av.) | 5,85,578 |
| 1944-45 | 4,40,089 |
| 1945-46 | 5,37,320 |
| 1946-47 | 17,98,060 |
| 1947-48 | 94,87,420 |
| 1948-49 | 78,65,299 |
| 1949-50 | 50,85,320 |
| 1950-51 | 20,79,874 |
| 1951-52 | 50,25,460 |
| 1952-53 | 49,97,341 |

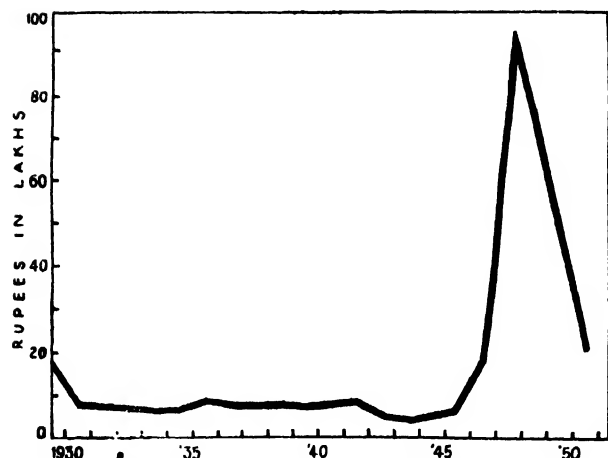


FIG. 36—IMPORTS OF ELECTRICAL LIGHTING ACCESSORIES

TABLE 42—COST OF PRODUCTION AND FAIR SELLING PRICE OF ELECTRIC FITTINGS

(Price per dozen in Rs. as. ps.)

| | Landed cost | Fair selling price |
|---------------|-------------|--------------------|
| Ceiling roses | 5 10 0 | 5 5 6 |
| Wall plugs | 8 12 0 | 11 6 0 |
| Switches | 10 0 0 | 7 13 7 |
| Lamp holders | 6 4 0 | 7 0 0 |

Cost of production—Table 42 gives the estimated cost of production and fair selling prices of ceiling roses, wall plugs, switches, and lamp holders produced in India. A protective duty of 31½% *ad valorem* in respect of imports of plastic electrical accessories from U.K. and 42% *ad valorem* for articles not of British manufacture is imposed on imported fittings. Imports of porcelain electrical accessories are subject to a revenue duty of 25% *ad valorem* (Indian Tariff Bd, Rep. *Plastics Industry*, 1949, 26).

BRASS LAMP HOLDERS

The manufacture of brass lamp holders had its beginning in 1943 when *Surya Engineering Works*, Tiljala (24-Parganas) commenced production. Due to the inadequacy of imports and the heavy demand for lamp holders, a number of factories came into existence during 1946-48. By 1950, there were in India 21 factories manufacturing brass lamp holders, of which 15 were in West Bengal, 2 each in Delhi and Bombay, and 1 each in Banaras and Phagwara (Punjab). The principal producers are *Kersons Manufacturing Co. of India, Ltd.*, Bombay (500,000), *Bharat Electric Manufacturing Co. Ltd.*, Bombay (270,000), *Guru Nanak Electro-mechanical Works*, Phagwara (187,000), *Union Metal Industries*, Tiljala (Dt. 24-Parganas) (153,500), *Surensons Ltd.*, Calcutta (150,000), *G.T.R. & Co. Ltd.*, Calcutta (120,000), *Ceico Ltd.*, Calcutta (108,000), *Bidyut Ltd.*, Calcutta (96,000), *Viswakarma Ltd.*, Howrah (72,000), *Steel & Metal Products Co.*, Calcutta (60,000), *Surya Engineering Ltd.*, Tiljala (48,000), *East Asiatic Industries Ltd.*, Calcutta (43,000), and *Essen Electrical Accessories Mfg. Co. Ltd.*, Calcutta (24,000), the figures in parenthesis denoting the annual production capacity in numbers of pieces produced. The industry, with an invested capital of c. Rs. 12 lakhs, provides employment for 330 workmen (Information from *Lamp Holders Manufacturers' Association of India*, Calcutta; Indian Tariff Bd, Rep. *Electric Brass Lamp Holders Industry*, 1950, 38).

Raw materials—The raw materials required for the manufacture of lamp holders are brass sheets (18-20 S.W.G.), brass pipes (bore thickness, 1/8 in.), brass wires and rounds (6-11 S.W.G.), spring steel wire (26 S.W.G.), porcelain insulators, straw

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boards, and polishing materials. All the materials are produced in India.

Brass sheets constitute more than 50% of the total cost of materials and 20% of the total cost of production. The approximate annual consumption of various raw materials by the industry are: brass sheet (18-20 S.W.G.), 100 tons; brass rod (3/16 in. diam.), 10 tons; brass pipes, 20 tons; phosphor bronze spring wire (26 S.W.G.), 1 ton; and porcelain insulators, 800,000 pieces (Information from *Lamp Holders Manufacturers' Association of India*, Calcutta).

Manufacture—Brass sheets are cut into strips in shearing machines, re-rolled if necessary to obtain the requisite gauge, and made into tops, bottoms, back plates (for batten type holders), and crowns. Terminal blocks and shade carrier rings are made of brass castings, partly from scrap obtained in processing tops and bottoms and partly from purchased scrap. Terminal contacts and screws are made from brass rods. Springs are electroplated to render them rust-resistant. The various parts are then assembled. The plants installed in many of the factories have been fabricated in India and the quality of holders produced has been accepted to be satisfactory. *Kersons Manufacturing Co. of India Ltd.*, Bombay, have installed imported automatic plant and machinery.

Production and Trade—Polished brass bayonet cap lamp holders with shade carrier rings, such as pendant holders, bracket holders ($\frac{1}{2}$ in. and $\frac{3}{4}$ in. with standard thread and $\frac{3}{4}$ in. with conduit thread), and batten holders (back plate, angle, and railway types) are the principal items produced in India. Small quantities of Goliath screw cap lamp holders are also manufactured. Holders with key or push buttons are not produced in India to any appreciable extent. The manufacture of miniature lamp holders used in automobiles will be shortly taken up in some of the factories. According to a recent estimate the demand for pendant, bracket, and batten type lamp holders is in the ratio of 50:30:20. Table 43 gives the production of brass lamp holders in India.

The present annual production is c. 800,000 pieces. Statistics regarding the import of electric brass lamp holders are not available. Some idea of the trend of imports by importers in Bombay, Calcutta, and Madras may be obtained from the figures given in Table 44.

U.K. was practically the only source of supply in 1948. During 1949, however, U.K. supplied 73%, Western Germany, 21%, and Japan, 2% of the imported lamp holders. During the first six months of 1950, the share of U.K. was 4%, that of Western Germany being 85%. Imports of brass lamp holders from U.K. are subject to a protective duty of 25%; the duty on articles of non-British origin is 37½% *ad valorem*.

Table 45 gives the fair ex-works prices of

TABLE 43—PRODUCTION OF BRASS LAMP HOLDERS*

| | Qty (no.) |
|------|--------------|
| 1947 | 286,836 |
| 1948 | 460,388 |
| 1949 | 315,744 |

* Indian Tariff Bd, Rep. *Electric Brass Lamp Holders Industry*, 1950, 36

TABLE 44—IMPORTS OF BRASS LAMP HOLDERS*
(Qty in numbers)

| | 1948 | 1949 | 1950† |
|----------|---------|-----------|---------|
| Bombay | 261,108 | 461,760 | 215,608 |
| Calcutta | 109,644 | 472,236 | 36,000 |
| Madras | 35,070 | 79,644 | 2,400 |
| Total | 405,822 | 1,013,640 | 254,008 |

* Indian Tariff Bd, Rep. *Electric Brass Lamp Holders Industry*, 1950, 12

† Jan.-June

TABLE 45—FAIR EX-WORKS PRICES OF ELECTRIC BRASS LAMP HOLDERS*

| | Per dozen Rs. as. ps. |
|--------------|--------------------------|
| Pendant type | 10 2 7 |
| Bracket type | 9 7 5 |
| Batten type | 9 15 5 |

Indian Tariff Bd, Rep. *Electric Brass Lamp Holders Industry*, 1950, 18

pendant, bracket, and batten type lamp holders as fixed by the Tariff Board. On the basis of the estimated distribution of the three types (50:30:20), the weighted average of the fair ex-works price for the three types works out to Rs. 9-14-7 per dozen. The prices in 1952 of the different types of brass lamp holders per dozen were as follows: $\frac{1}{2}$ in. bracket holders, Rs. 12-8; $\frac{3}{4}$ in. bracket holders, Rs. 14; $\frac{3}{4}$ in. bracket holders, Rs. 16; pendant holders, Rs. 13-8; and batten holders, Rs. 13-8.

It is difficult to estimate the domestic demand for brass lamp holders. For lighting purposes in households, brass holders are being replaced by bakelite holders owing to the relative cheapness of the latter. Bakelite holders are, however, less durable. They are not suitable for use in railways, dock areas, or factories. The manufacturers estimate the annual demand for brass lamp holders at 6 lakhs assuming that the demand is divided between bakelite holders and brass holders in the ratio of 50:50. The importers estimate the demand to be 16-17 lakhs after taking into account the spurt in house building and general industrial activity. The target of production for 1952 estimated by the Development Committee of the Directorate-General of

Industries and Supplies was 17.28 lakhs. The Tariff Board estimates the total annual demand during the next two years at 9 lakhs.

CONDUIT PIPES

Conduit pipes are required for covering wires inside houses. Two types of conduit pipes are manufactured, solid drawn and welded. They may be either galvanized or enamelled and vary in size from $\frac{1}{2}$ in. to $2\frac{1}{2}$ inches in diameter.

India depended almost entirely on imports for conduits prior to World War II, the imports being mainly from U.K. and Germany. The *National Conduits Ltd.*, Delhi commenced production of conduit pipes in 1940. The *Indian Conduit Co. Ltd.*, Calcutta and a few other factories have since come into existence. At present there are seven factories with a total annual capacity of 7,560,000 feet. Clay conduit pipes are manufactured by *A. K. Sarkar Industries Ltd.*, Calcutta.

The raw materials required for the production of conduit pipes are black steel sheet, enamel paint, and pig iron. The sheets should have a tensile strength of not less than 18 tons and not more than 24 tons per sq. in. section, and an elongation of not less than 15% in a length of 8 inches. A part of the requirements of steel sheet is met by indigenous production; a part is imported. The other raw materials are available in the country.

Black steel sheets are cut into strips, rolled into pipes, and welded. Rollers and welding plants installed in most of the factories are fabricated in India. In the process adopted in the *Hume Pipe Co.*, Bombay the pipes are joined when they are in a melted condition. The welded products are threaded at the ends and coated with enamel paint or are galvanized.

Conduit accessories—bends, circular boxes, tangent entry boxes, oblong boxes, tees, couplings, clips, saddles, spacing plates, hooks, reducers, lock nuts, etc.—are made either from pipes or from malleable iron by casting. Conduit pipes and accessories are manufactured according to British Standard Specifications.

Table 46 gives the production of conduit pipes in India.

Imports—Tables 47 and 48 give imports of conduit pipes from U.K. and U.S.A. into India.

TABLE 46—PRODUCTION OF CONDUIT PIPES

| | Qty (ft.) |
|------|--------------|
| 1948 | 1,707,923 |
| 1949 | 2,948,824 |
| 1950 | 2,966,919 |
| 1951 | 3,968,881 |
| 1952 | 3,694,463 |

TABLE 47—IMPORTS OF CONDUIT PIPES FROM U.K.*

| | Qty (tons) | Val. (£) |
|------|---------------|-------------|
| 1942 | 121 | 5,500 |
| 1943 | 172 | 6,694 |
| 1944 | 202 | 8,372 |
| 1945 | 329 | 13,684 |
| 1946 | 567 | 32,581 |
| 1947 | 33 | 2,801 |
| 1948 | 101 | 7,909 |
| 1949 | 397 | 28,066 |
| 1950 | 1,123 | 65,508 |

* Tr. U.K.

TABLE 48—IMPORTS OF CONDUIT PIPES FROM U.S.A.*
(Qty in lb. and val. in \$)

| | Qty | | Val. | | |
|------|-----------------|--------|-----------------|--------|----------|
| | Iron & steel | Others | Iron & steel | Others | Fittings |
| 1948 | 68,417 | n.a. | 5,093 | 3,262 | .. |
| 1949 | 414,354 | 2,600 | 46,916 | 524 | 9,165 |
| 1950 | 146,025 | 16,772 | 18,064 | 9,836 | 30,314 |
| 1951 | 221,129 | 16,800 | 28,485 | 2,050 | 12,183 |

* U.S. Exports of Domestic & Foreign Merchandise

Insulators

Any dielectric can be used as an insulator in the transmission of electrical energy. Materials, such as porcelain, glass, mica, rubber, silk, and paraffin, have long been employed for this purpose. Porcelain and glass are used for the fabrication of different forms of insulators; others are used in the unformed condition.

The use of porcelain as an insulator dates back to the inception of the electrical industry. Its hardness, relative immunity to humidity effects, and the ease with which it can be formed into diverse shapes have given porcelain a unique place among insulating materials in electro-technical practice.

Electric porcelain is used for low and high tension work, house-hold electrical fittings, and industrial equipment. Special ceramic bodies, such as steatite, rutile, cordierite, high alumina, and clinoenstatite, are used for high frequency work, e.g. radio and radar.

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Low tension Insulators—Low tension insulators are used for a.c. and d.c. power supplies of not more than 600 volts. Table 49 gives the composition of porcelain bodies used for low tension insulators.

Important among the properties of low tension insulators are dielectric or breakdown strength and specific resistivity. The dielectric strength

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TABLE 49—BODY COMPOSITION OF LOW TENSION ELECTRICAL PORCELAIN*

| Component | Composition (%) | | | | |
|--------------|-----------------|----|----|----|----|
| | A | B | C | D | E |
| Ball clay | 10 | 35 | 20 | 18 | 11 |
| Kaolin | 28 | 18 | 20 | 17 | 28 |
| Feldspar† | 35 | 24 | 40 | 33 | 34 |
| Flint | 25 | 21 | 10 | 10 | 26 |
| Talc | 2 | .. | .. | .. | 1 |
| whiting | .. | 2 | .. | .. | .. |
| Pyrophyllite | .. | .. | 10 | 22 | .. |
| Fire to cone | 9 | 10 | 11 | 12 | 12 |

* Newcomb Jr, 242

† Nepheline syenite may be used as flux in place of feldspar, when a lower firing temperature can be employed

TABLE 50—PROPERTIES OF ELECTRICAL PORCELAIN BODIES*

| | Minimum | Maximum |
|--|----------------------|----------------------|
| Physical : | | |
| Sp. gr. | 1.90 | 2.48 |
| Compressive strength, lb./sq. in. | 30,000 | 65,000 |
| Tensile strength, lb./sq. in. | 1,500 | 6,000 |
| Modulus of rupture, lb./sq. in. | 3,000 | 8,500 |
| Water absorption, %† | 0.2 | 2.0 |
| Impact resistance, ft. lb./sq. in. | 0.50 | 0.90 |
| Linear expan. coeff., in./°C. | 2.5×10^{-6} | 5.5×10^{-6} |
| Thermal conductivity cal/sec./sq. in./in. °C | 0.0020 | 0.0039 |
| Electrical : | | |
| Dielectric strength, volts/mil | 90 | 200 |
| Dielectric constant | 6.0 | 7.5 |
| Volume resistivity, meg/cu. in. | 300,000 | 3,000,000 |
| Power factor at 1,000 kc | 0.60 | 0.95 |

* Newcomb jr, 245

† Water absorption of porous refractory insulator bodies may be 10% or higher. Such bodies are employed to resist rapid changes of temperature, as in electrical ranges, rheostats, and immersion heaters

is 20-30% higher with d.c. than with a.c. and decreases at high frequencies. Also, insulators formed by plastic processes, i.e. casting, jiggering, and extrusion, have a higher dielectric strength than those shaped by dry-pressing. At 98% relative humidity the resistivity of a glazed insulator is of the order of 0.1×10^{12} ohm/sq.cm.; that of an unglazed insulator is 0.001×10^{12} ohm/sq.cm. Table 50 gives the properties of electric porcelain bodies.

Low tension insulators are manufactured in both glazed and unglazed forms. In dry atmospheres vitrified unglazed insulators are quite satisfactory. The bulk of porcelain fittings used in open wiring or knob- and tube-wiring is glazed on one side. Such fittings are available in a variety of forms, such as nail knobs, tubes, and cleats. Other items of low frequency insulation are outlet boxes and sockets. Insulators of various shapes are required for use in household appliances.

As glazing improves surface resistivity, insulators required for use in humid atmospheres are invariably glazed. Glazed insulators are used in lightning arresters in radio receivers, telephone and utility outlets, and neon signs.

High tension Insulators—Porcelain insulators required for high tension transmission and distribution are required to be effective at high voltages and under extreme climatic conditions of rain, snow, high winds, and searing heat. Two types of high tension insulators are in use—the suspension type and the pin type.

Suspension insulators are designed to keep the high tension wire at a distance from the metal framework of supporting towers and so obviate the danger of arcing and short circuiting. They are used in strings for voltages above 66,000, each unit being attached to the next by hardware fittings. The shells are coated with high temperature brown glaze which is fired with the body in a single firing operation. The sizes usually manufactured are 6 in., $7\frac{1}{2}$ in., and 10 in. diam. Table 51 gives particulars of suspension insulators.

Pin type insulators are usually employed in power transmission lines operated below 70,000 volts and in all power distribution circuits. The insulator is fixed on a malleable steel pin and supported upon a wooden or metallic cross arm. It is glazed and is almost completely self-cleaning when exposed to rainfall. Special glazes are applied to eliminate radio disturbances caused by brush or carbon discharges in tie-wire grooves and pin holes. Pin type insulators are rugged and give long service. Table 52 gives the characteristics of the more common pin type insulators.

TABLE 51—PARTICULARS OF SUSPENSION TYPE INSULATORS*

| | Diam. of shell (in.) | | |
|---|----------------------|-----------------|------------------|
| | 6 | $7\frac{1}{2}$ | 10 |
| Mechanical and electrical strength, lb. | 10,000 | 15,000 | 15,000 |
| Dry flashover, volts | 60,000 | 70,000 | 80,000 |
| Wet flashover, volts | 35,000 | 40,000 | 50,000 |
| Leakage distance, in. | $7\frac{1}{2}$ | 8 $\frac{1}{2}$ | 12 $\frac{1}{2}$ |
| Spacing, in. | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ |
| Net wt., lb. | $5\frac{1}{2}$ | 8 $\frac{1}{2}$ | 13 |

*Newcomb Jr, 250

TABLE 52—CHARACTERISTICS OF COMMON PIN TYPE INSULATORS*
Diam. of porcelain shell (in.)

| | 3½ | 5½ | 7 | 9 | 12 |
|--------------------------|--------|--------|--------|---------|---------|
| Nominal voltage rating | 2,300 | 7,500 | 15,000 | 45,000 | 55,000 |
| Dry flashover, volts | 37,000 | 70,000 | 91,000 | 125,000 | 150,000 |
| Wet flashover, volts | 20,000 | 40,000 | 50,000 | 80,000 | 110,000 |
| Wet arcing distance, in. | 1½ | 2½ | 3½ | 5½ | 7½ |
| Leakage distance, in. | 4 | 9½ | 12½ | 18 | 28½ |
| Mechanical strength, lb. | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| Net wt., lb. | 1½ | 3 | 5 | 15 | 21 |

* Newcomb Jr, 254.

A great variety of insulators other than suspension and pin types, e.g. high voltage tubes and bushings, lead-in insulators, guy line insulators, housing for line cut-outs, fuse cut-outs, coil forms, transformer housings, and specialized items, are used in high tension work. Resistance to thermal shock is of prime importance in some of their applications, e.g. for use in transformers. Steatite has long been used in Europe for certain types of high tension insulators.

A special type of high tension insulator is the spark plug used in internal combustion engines. Formerly it was made of a dense porcelain body of the clay-flint-feldspar type, thoroughly vitrified at cone 16 or higher. Modern engines require spark plugs with high mechanical and dielectric strengths at high temperatures and good resistance to thermal shocks. Clay and sillimanite bodies with dumortierite ($8\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot \text{B}_2\text{O}_3 \cdot \text{H}_2\text{O}$) as flux have been developed to withstand such severe service requirements. Spark plugs made of sintered alumina possess high dielectric strength and high volume resistivity at elevated temperatures. Spark plugs are also made with corundum body (*Rep. Progr. appl. Chem.*, 1949, 34, 209).

Raw materials—The raw materials required for the manufacture of porcelain insulators are chiefly plastic materials, such as clay, kaolin, and bentonite, and non-plastic materials, such as silicon (quartz, sand, or flint), feldspar, stone, pegmatite, lime, magnesite, sillimanite, and alumina. The porcelain body used in the manufacture is a combination of both the types of raw materials used in different proportions. The non-plastics serve as 'opening' materials preventing excessive shrinkage during drying and firing. Some of them act as fluxes helping and speeding up the densification of the body. The glazing materials are also derived from these raw materials.

Two types of glazes are employed: low temperature glazes employing frits and high temperature glazes without frits. Glass forming substances for frits are silica, feldspar, dolomite, magnesite, zinc oxide, etc. As the glaze is applied to the body in the form of a water suspension, water soluble salts, when used, should be rendered insoluble* by fusion with silica or silicon com-

pounds. Glazes melting at temperatures above 1,250 do not contain frits.

Glazes containing no frits are easier to prepare and porcelain manufacturers make such glazes themselves. Frit-containing glazes are generally purchased. Sometimes glazes are employed on pre-fired articles, particularly if they are stained. Special glazes, such as metallic glazes and coatings, are used for certain types of insulators.

Manufacture—The processes employed in shaping ceramic wares (cf. *Wlth of India*, Pt II, 82) are generally used in fabricating insulators also. The plastic body is treated differently to suit different shaping processes. For jollying, turning, and extruding, the mix is rendered homogeneous in a de-airing pug mill. For casting, sodium silicate or sodium carbonate solution is added in small amounts for deflocculating. For pressing, the body is dried, mixed with a lubricant, and disintegrated.

High tension insulators for power transmission lines, bushings, switchgear insulators, and post insulators, which have a round section, are manufactured by such methods as hot pressing, jiggering and jollying, extruding, and turning. Bigger sizes and complicated types are made by assembling sections, the joints being luted with clay slip, so that they become homogeneous with the rest of the body during the firing. Often a combination of one or more methods is used. Pin and suspension type insulators are made by pressing lumps of plastic body into plaster-of-Paris moulds and jollying the inner surface. Insulators with circular cross-section, such as bushings, solid core insulators, 'motor' type suspension insulators, and Langstab insulators are made by turning or jollying extruded cylinders which form the outside sheds. Medium and large insulators are turned in the semi-hard 'green' state while smaller ones are turned after they are completely dried and hardened ('white' state). Insulators with sheds of larger diameter are made by joining separate sheds to the protruding shoulder by sticking with slip.

Long insulators with symmetrical cross-section are formed by extrusion. The rods and tubes so made are cut into pieces of the required length.

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This method is also used for preparing discs of intricate shapes often containing holes. Pug mills as well as vertical and horizontal presses are used for extrusion.

Low tension insulators are shaped mostly by pressing in steel dies. Wet pressing is employed for relatively simple shapes. The plastic body is placed on the lower part of the metal die while the upper part is pressed on it. Complicated shapes are made by semi-dry and dry pressing methods. In the former, the dry body is disintegrated into a powder, mixed with small quantities of water, oil, or paraffin, and pressed. In the dry pressing method, used for steatite and talcum containing bodies, the finely divided granulated body is densified under high pressure.

Shaped articles are dried and glazed. The glaze is applied by dipping or spraying to half dry (leather hard) or to completely dry articles. Spraying is the method adopted for applying glaze to large sized or thin walled insulators. Glazed insulators are put in saggers and fired in intermittent up- or down-draught kilns or in continuous tunnel kilns. Close control is essential. Over-firing causes vesicular (bubbly) structure to develop. The body composition remaining the same, a high firing temperature improves the dielectric strength and resistance to thermal shock and also mechanical strength. Fired insulators are cooled gradually, sorted, and tested to specifications.

THE INDIAN INDUSTRY

Porcelain electrical insulators are produced in India by Messrs. *Bengal Potteries Ltd.*, Calcutta, *Bengal Porcelain Co. Ltd.*, Calcutta, *Hindustan Potteries*, Calcutta, *A. K. Sarkar (Industries) Ltd.*, Calcutta, *Government Porcelain Factory*, Bangalore, and *Parasuram Pottery Works Co. Ltd.*, Morvi. The total annual capacity of the factories is 6,070,800 low tension insulators and 512,400 high tension insulators. In the pre-war years, production was mainly confined to low tension insulators required by the Posts and Telegraphs Department, electrical utility undertakings, and radio industry. Since the commencement of World War II, attempts have been made to produce high tension insulators. Organized production started in 1947. A scheme for the manufacture of high tension insulators in the Damodar Valley area is under consideration.

Insulators manufactured in India are (1) *Low tension insulators*: pin type, line post, shackle, spool or reel type, fuse handles, porcelain parts for iron clad switches, cable rack insulators, fan regulators, cut-outs, cleats, porcelain tubes, lamp holders, etc.; in addition, low tension insulators required for use in domestic appliances, e.g. electric irons, toasters, refrigerators, and fans, are produced in India; and (2) *High tension insulators*:

pin type, line post, strain, suspension, switch, and bus insulators.

Raw materials—All the raw materials, except ball clay, are available in the country. A survey of raw materials required for high tension insulators has been carried out recently by the Government of India in collaboration with the Damodar Valley Corporation and the Governments of Bihar and West Bengal. Preliminary reports indicate that materials of suitable quality (tested in the *Government Porcelain Factory*, Bangalore) are available in the Damodar Valley area.

Manufacture—Feldspar and quartz are dry ground separately in edge runner mills, then with water in ball mills to a fine state of division to pass 160 mesh lawns. The ground charge is let into screw blungers and mixed with kaolin and ball clay slip. The slip is passed over electro-magnets to remove free iron particles, passed through sieves (160 mesh), and led into stirring tanks. The slip is filter pressed and the cakes fed into de-airing pug mills from which it is extruded into blanks of different sizes for being shaped into insulators. The average body composition as made by one of the firms is as follows: China clay, 50%; feldspar, 25%; and quartz, 24%.

Low tension insulators are fabricated by jolleying and turning. Outer shapes are given by plaster moulds and inner shapes are cut by profiles according to designs. Some types of insulators are amenable to shaping directly from stiff clay stock by trimming while revolving on a spindle. Sometimes 2 or 3 parts are joined together by clay slips. For the manufacture of pin-type insulators, the blanks from the pug mill are shaped by hand, placed in plaster-of-Paris moulds, and shaped by hot plastic pressing machines. Shaped insulators are allowed to dry till leather hard and shaped in trimming machines.

Strain insulators, fuse handles, cable racks, pipes, etc. are made by casting clay slips in plaster-of-Paris moulds. Smaller parts, such as cleats, fuse units, fan regulators, cut-outs, and lamp-holders, are made by dry or semi-dry pressing in steel moulds.

The methods of manufacture of high tension insulators are similar to those of low tension insulators. The final products are required to satisfy rigid electrical and mechanical tests.

Fabricated articles are dried in artificial drying chambers at c. 70°, dipped in the glazing slip, and fired for maturing the body and the glaze. Bigger pieces are glazed by spraying. Porcelain insulators required for use in locations where humid conditions are never encountered, such as porcelain sockets for lamps, tubes, nail knobs, outlet boxes, fan regulators, switch parts, etc.,

are not glazed. All insulators for overhead distribution and power transmission are glazed. A suitable glazing composition consists of: CaO, 0.7; K₂O, 0.3; Al₂O₃, 0.6; and SiO₂, 6.0 parts; it is compounded with clay, feldspar, limestone, and quartz.

Insulators are usually fired by the single-fire process to 1,300–1,350°. They are packed in saggars and loaded into the lower chamber of a two-chambered round draught kiln fired with coal. The upper chamber of the kiln, which is maintained at c. 800°, is used for biscuiting certain types of insulators. Firing and cooling take 72–80 hours. Insulators fabricated by the dry process are subjected to two firings.

An electric tunnel kiln is used in the *Government Porcelain Factory*, Bangalore. The kiln is a single tunnel 280 ft. long × 18 in. wide × 2 ft. high. The installed capacity of the kiln (c. 300 kw.) is 1½ tons of fired ware in 24 hours. Glazed articles are loaded on cars and passed through the kiln; 74 cars are used of which 64 are inside the kiln. The kiln may be divided into 3 zones—preheating zone, hot zone, and cooling zone. Up to the end of the preheating zone, no heating elements are employed, and the ware is heated gradually to c. 500° by radiation from the hot zone. The hot zone is heated by nickel-chromium heating elements and Globar rods and a reducing atmosphere is maintained to impart a milky whiteness to the glazed ware. Fired insulators after passing through the cooling zone are taken to the sorting section. The Bengal

TABLE 53—PRODUCTION OF INSULATORS IN INDIA

| | Qty. (no.) | |
|------|------------|-----------|
| | H.T. | L.T. |
| 1947 | 74,177 | 1,429,905 |
| 1948 | 89,879 | 2,503,031 |
| 1949 | 136,750 | 2,239,214 |
| 1950 | 173,846 | 1,279,135 |
| 1951 | 244,800 | 1,432,800 |
| 1952 | 325,200 | 3,064,800 |

TABLE 54—IMPORTS OF ELECTRICAL PORCELAIN WARE

| | Val. (lakh Rs.) |
|------------------------|--------------------|
| 1937/38–1938/39 (av.)* | 1,40,800 |
| 1939/40–1943/44 (av.) | 1,01,460 |
| 1944–45 | 1,78,489 |
| 1945–46 | 94,585 |
| 1946–47 | 1,79,596 |
| 1947–48 | 1,88,852 |
| 1948–49 | 1,68,684 |
| 1949–50 | 3,75,378 |
| 1950–51 | 2,56,556 |
| 1951–52 | 5,46,510 |
| 1952–53 | 4,42,757 |

* Listed as a separate item since 1937–38

TABLE 55—IMPORTS OF ELECTRICAL WARE (INCLUDING INSULATORS) OF PORCELAIN, EARTHENWARE OR STONEWARE FROM U.K.*

| | Qty. (cwt.) | Val. (£) |
|------|----------------|-------------|
| 1942 | 2,310 | 13,191 |
| 1943 | 4,071 | 19,899 |
| 1944 | 6,176 | 40,059 |
| 1945 | 5,577 | 35,101 |
| 1946 | 3,781 | 26,881 |
| 1947 | 5,302 | 48,943 |
| 1948 | 9,953 | 100,201 |
| 1949 | 15,069 | 137,901 |
| 1950 | 13,809 | 133,011 |

* Tr. U.K.

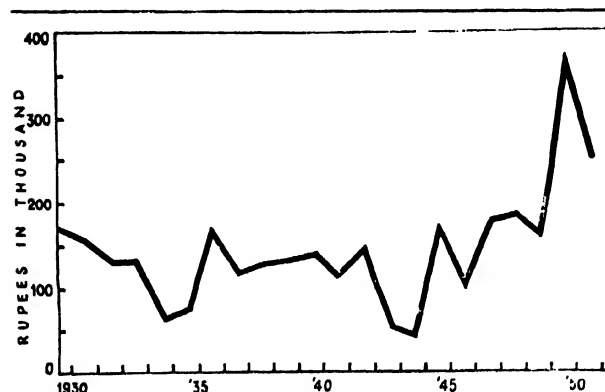


FIG. 37—IMPORTS OF INSULATORS

Potteries Ltd., Calcutta, have two gas-fired tunnel kilns for firing insulators.

High tension insulators are subjected to the following tests: (1) dry flashover test, (2) wet flashover test, (3) temperature cycle test, (4) puncture test, (5) mechanical test, and (6) porosity test. The insulators are required to conform to the British Standard Specification. The High Voltage Laboratory of the Indian Institute of Science, Bangalore, will be installing impulse and high frequency testing equipment.

The Posts and Telegraphs Department is the biggest consumer of porcelain insulators in the country. I. S. Specification 283-1951 for porcelain insulators for telegraph and telephone lines prescribes the following tests: insulation resistance, thermal shock resistance, mechanical strength, porosity, visual inspection, and gauge.

Production and Trade—Table 53 gives the production of insulators in India.

Imports—Table 54 gives the value of electrical porcelain imported into India.

Insulators are imported mainly from U.K. Small quantities were being imported from Japan prior to World War II. Table 55 gives imports of electrical insulators from U.K.

Indian requirements of H.T. insulators are estimated to be 2,000 tons per annum [*I. & S. Bull.* 1949, 2 (2) 28].

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OTHER CERAMIC INSULATORS

High frequency insulators are made from special ceramic bodies. The requirements of high frequency insulators are: low power loss, high dielectric strength, and high resistivity, all of which should be little affected by temperature changes. For insulating purposes a ceramic body with low dielectric constant should be used as reduction of power loss is the main consideration. For condenser work the dielectric constant should be high so that a unit of small size may have sufficient capacitance. Insulators for use in radio equipment should have high dielectric strength and also high resistivity so that the bulk may be small; they should also have low power loss for ensuring selectivity. For transformer work the insulator should have a low power factor (Newcomb Jr, 257).

The mechanical properties required in high frequency insulators are: smooth non-absorbent surface, high mechanical strength, and relatively low thermal expansion. They should be formed and shaped to close tolerances (Newcomb Jr, 257).

A variety of bodies, such as clinoenstatite (steatite), cordierite, rutile, titanate, zircon, lava, and porous insulating bodies, are employed for high frequency insulators.

Clinoenstatite—Insulators with clinoenstatite bodies are made mainly of high purity steatite. Impurities, if present, should be below specified limits—iron oxide, 1% (max.), lime, 1.5% (max.); and alumina, 2% (max.). Iron oxide causes dielectric losses while lime lowers the power factor and shortens the firing range of the body. Excess of alumina increases power loss. Small quantities of fluxes and clay are added to steatite to give a dense body possessing the required dry and green strengths. Potash feldspar is used as flux; this is preferred to soda spar as the latter has an adverse effect on the power factor. Carbonates of calcium, barium, and magnesium, which improve the power factor and reduce the shrinkage, are also used as fluxes. Table 56 gives the composition of steatite bodies.

On heating the talc-clay-feldspar mix to a high temperature magnesia and silica combine to give magnesium silicates which, at temperatures exceeding 1,270°, form stable clinoenstatite ($\text{MgO} \cdot \text{SiO}_2$). The fired body consists mainly of clinoenstatite crystals bonded by a feldspathic glass. When alkaline earth carbonates are used, instead of feldspar, in the mix the fired body consists almost entirely of clinoenstatite crystals mixed with alkaline earth silicates.

Insulators with clinoenstatite bodies are made by extruding, machining, pressing, and slip casting. The firing temperature is about 1,350°. Close temperature control during the firing is necessary on account of the relatively short firing

TABLE 56—COMPOSITION OF STEATITE BODIES*
(Figures give percentages)

| | A | B | C | D |
|------------------------|----|----|-------|----|
| Steatite talc | 87 | 90 | 60.0 | 88 |
| Potash feldspar | 6 | 5 | .. | .. |
| Plastic kaolin | 7 | 5 | 15.0 | 5 |
| Magnesium carbonate | | | 7.5 | |
| Barium carbonate | | | 17.5 | |
| Calcium carbonate | | | .. | 1 |
| Firing temp (cone no.) | 14 | 13 | 12-13 | 13 |

* Newcomb Jr, 258

A and B are normal steatites; C and D are high frequency steatites

range (25–30°). A high fire, low expansion glaze is used (satisfactory composition for single firing process; feldspar, 37%; whiting, 15%; flint, 35%; and ball clay, 13%).

Clinoenstatite bodies are dense and strong. They have a low power factor which remains constant at 0–100°, increasing slightly up to 300°. They are used in the radio industry for wave band switches, sockets and supports for tubes, trimmer bases, condenser plates, coil forms, crystal holders, coaxial cable insulators, antenna insulators, resistor shafts, stator supports for air condensers, relay insulators, and other applications (Newcomb Jr, 260).

Rutile bodies—Titania (TiO_2) has a high dielectric strength and a negative dielectric coefficient with increasing temperature. On account of these properties rutile insulators are used in radio condensers with fixed dielectric constant. As titania is difficult to vitrify, rutile bodies are made by firing mixes containing roasted rutile crystals and feldspar, clay, or other fluxing material, although such additions lower the dielectric constant. A composition containing: TiO_2 , 90%; calcium-titanium silicate, 3.33%; MgO , 3.33%; and beryllium oxide, 3.33%, has a power factor of 0.00036 at 1,000 kc., dielectric strength of 144 volts/mil, and thermal linear expansion of 7.2×10^{-6} in the range of 100°–500°; the body is dense and strong on firing, the firing shrinkage being c. 27% (Newcomb Jr, 263).

Rutile insulators are used in fixed and trimmer condensers in radio receivers and other equipments where the capacitance is the primary consideration.

Titanate bodies—Titania ceramic with dielectric constants ranging from 110 to 6 and with negative, zero, or positive temperature coefficients, have been prepared for use in high frequency equipments. Titanates of magnesium, calcium, barium, strontium, zinc, and lead have dielectric constants up to or exceeding 10,000. Titanate bodies are made of rutile (60–90%) with one or more of the following oxides: MgO , ZnO ,

TABLE 57—COMPOSITION OF ZIRCON PORCELAINS*
(Figures give percentages)

| | A | B | C | D | E |
|------------------------------|-------|------|------|------|----|
| Zircon silicate | 59.25 | 66.7 | 68.5 | 59.2 | 35 |
| Calcium-zirconium silicate | 7.41 | 22.2 | 22.6 | 29.6 | 20 |
| Magnesium-zirconium silicate | 7.41 | .. | .. | .. | 10 |
| Barium-zirconium silicate | 7.41 | .. | .. | .. | 10 |
| Ball clay | 18.52 | 11.1 | 8.9 | 11.2 | 25 |

* Newcomb Jr., 268

BaO, PbO, and BeO. A titanate body consisting of magnesium ortho-titanate ($2\text{MgO} \cdot \text{TiO}_2$) shows extremely low dielectric loss. Titanate bodies have lower dielectric constants than rutile bodies and the constants vary but little (-20×10^{-6} to -30×10^{-6} per °C.) with change in temperature (Koenig, *Industr. Engng Chem.*, 1948, 40, 1782; Newcomb Jr., 265).

Titania ceramics are used for high frequency applications, e.g. resistors, condensers of high capacity but of small size, trimmers, and temperature-compensating components.

Zircon bodies—Zircon bodies have higher firing ranges (min., 200°F.) than other types of low loss bodies and remain dense throughout the firing range; on account of these properties they are not liable to underfiring or overfiring. Table 57 gives the composition of zircon porcelains.

Zircon insulators are formed by pressing, extrusion, plastic forming, or casting and fired in kilns without excessive loss. They are dense and impervious, have high strength and excellent thermal properties, low power factor and low loss factor at temperatures below 200°; they are inferior to clinoenstatite bodies at higher temperatures.

Cordierite bodies—Cordierite bodies are produced (firing temp., c. 2,200°F.) from mixtures of clay and talc + alumina, magnesia, forsterite, or mullite. In composition they are somewhat similar to cordierite ($2\text{MgO} \cdot 2\text{Al}_2\text{O}_3 \cdot 5\text{SiO}_2$). The thermal expansion is low, the expansion depending on the quantity of cordierite crystals present in the body. They are therefore highly resistant to thermal shocks. They are, however, porous, possess poor mechanical strength, and are somewhat inferior to steatite in insulating properties. Insulators with cordierite bodies are shaped by clay-forming processes, the actual method applied depending upon the type of product required. Cordierite bodies are difficult to glaze owing to their low expansion; the difficulty may be surmounted by adding the glass-forming flux at the time of firing to produce self-glaze on the surface. •

Insulators with cordierite bodies are used in coil forms and as supports for resistance wires.

Glass Insulators—Toughened glass is used for certain types of insulators due to its electrical and mechanical properties. The process of toughening or tempering imparts to glass the capacity to withstand mechanical and thermal stresses. The process consists in heating glass to a temperature considerably above its strain temperature and then cooling rapidly, usually by blowing air, under controlled conditions. The interior of the glass is in a state of tension and the rate of cooling is so adjusted that the maximum tension in the central layer does not exceed the 'safe' value.

By virtue of its high resistance to thermal shock and high coefficient of expansion, toughened glass can be used with advantage with metal caps or pins. Soda-lime glass, which has a coefficient of linear expansion of 8.7×10^{-6} /°C. is used for this purpose.

Power line insulators are composed of either one piece glass pressings or of a number of pressings cemented together by an aluminous cement. Molten glass at 1,000° is poured into a crucible cast-iron mould with chill-hardened working surfaces and a plunger of the same material is employed for pressing the glass into the required shape. The moulded glass is then placed in an 'equalizing' furnace of the rotating hearth type at c. 700° for equalizing the temperature throughout the piece. The glass is then rapidly cooled by blowing compressed air. Treated pieces are subjected to thermal shock test and approved ones are partially de-toughened by exposure to 450° for a specified period. This operation increases the safety factor by lowering the tension in the central layer. The tension in the finished insulator is c. 8,000 lb./sq. in. Pin type insulators are fitted with copper or aluminium caps and screwed with copper ferrules (Hogg, *J. Instn elect. Engrs*, 1940, 87, 615).

Toughened glass insulators have satisfactory life and mechanical strength. They are proof against puncture by lightning surges and are able to withstand power arcs. Because of their transparency, faults can be easily detected in glass insulators (Hogg, *J. Instn elect. Engrs*, 1940, 87, 615).

Lamps

Important among the electric lamps used as light sources are arc lamps, incandescent lamps, and discharge lamps. Of these, the incandescent electric lamp is by far the most important. It is widely used for lighting purposes on account of its simplicity, low cost, and safety.

ARC LAMPS

The arc is started by impressing a voltage across two carbon electrodes in contact and then

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separating them. The high field and current density at the time of the break initiates the arc. The arc vaporizes the electrode material forming a conducting ionized vapour in between the poles and a luminous bridge is maintained.

Arc lamps are of 3 types: (1) the low intensity arc lamp, (2) the flame arc lamp, and (3) the high intensity arc lamp. The light emanates from the incandescent crater of the positive electrode in low intensity and high intensity arcs and from the heated, luminous ionized gases surrounding the arc in the flame arc.

The electrodes contain small quantities of arc supporting and flame materials, their relative proportion depending on the type of arc desired (cf. Carbon electrodes). They are usually copper plated to increase the electrical conductivity, but the positive electrodes of high intensity arcs designed to carry more than 100 amp. are not generally plated.

Arc lamps are operated on direct current. The flame arc, however, can also be operated on alternating current. The current is supplied through holders attached to the electrodes behind the tips. Arc lamps are equipped with automatic mechanisms for starting the arc and for adjusting the electrodes.

The high intensity arc lamp is used in photography, motion picture projection, and Army and Navy searchlights. The arc approaches a point source of light and is useful in precision optical systems. The low intensity arc lamp is used to a limited extent for motion picture projection.

The "sunshine" flame arc lamp is used in still and motion picture photography on account of the daylight character of the light. It is used for the rapid determination of the effect of exposure to sunlight on protective coatings, dyed fabrics, and other materials.

Special arc electrodes and constructions are used for the production of 6432.5696A° cadmium line which is used as the standard of length.

INCANDESCENT LAMPS

The incandescent lamp consists of a resistance wire or filament hermetically sealed in a glass bulb which is either evacuated or filled with an inert gas. The filament, usually of tungsten, is supported on molybdenum wires and mounted on a glass stem press into which lead-in wires are fixed. The lamp base is fixed to a brass cap.

Carbon filaments were being employed in the early stages of the development of the incandescent lamp. Their use had to be abandoned as carbon vaporizes at high temperatures and it was not possible, even by using vacuum, to obtain a lamp with a working temperature exceeding 2,100°K and a life of more than 600 hours; also the light efficiency did not exceed 3-3.3 lumens per watt (lm/W). Later, tantalum and osmium

were tried. Tungsten filaments are now widely employed, but carbon filaments are still in use on account of their robustness, wherever mechanical shocks have to be withstood. The lighting efficiency with tungsten filaments is about 8/10 lm/W for a lamp life of 1,000 hours (Federov, 82).

Tungsten also evaporates in vacuum at high temperatures causing blackening of the bulb and consequently loss of light and early failure of filament. The development of gas-filled lamps in 1913 was a notable advance. The lamp is filled with an inert gas and the pressure of the gas within the bulb is maintained at atmospheric pressure. Filament evaporation is minimized and high working temperatures can be employed. Due to thermal conduction and convection by the gas, however, the filament gets cooled. The heat lost through thermal conduction is small but that due to convection, calculated as percentage of the power input, increases from 9.2 in a 500-watt lamp to 24.5 in a 40-watt lamp. In lamps of low wattage, the loss is appreciable. For reasons of economy, therefore, lamps of low wattage, especially those below 40 watts, are evacuated. The working temperature in a gas-filled lamp may be as high as 3,000°K, corresponding to a lighting efficiency of 20 lm/W for a lamp life of 1,000 hours (Moon & Spencer, 50; Federov, 83).

In gas-filled lamps, the evaporated filament particles are carried upwards by convection currents and deposited in the lamp neck; the deposit, however, has little or no effect on the light output of the lamp.

Incandescent electric lamps are manufactured in all industrially advanced countries. U.S.A. is the biggest producer with Japan coming next. In 1939 U.S.A. had 55 establishments with 11,187 workers engaged in the manufacture of electric lamps.

U.S.A. production in 1945 was 792,620,000 incandescent lamps (total lumen hours, 760,000,000). The annual output of electric lamps in a few other countries prior to World War II were as follows: Japan, 300,000,000; Germany, 100,000,000 (+200,000,000 miniature lamps); Holland, 100,000,000; U.K., 100,000,000; France, 70,000,000; Canada, 30,000,000; Sweden, 12,500,000; and India, 2,750,000.

THE INDIAN INDUSTRY

The manufacture of incandescent electric lamps in India was started in 1932 at Calcutta by *Bengal Electric Lamp Works Ltd.*, with a capital of Rs. 18,000, 11 workers, and hand operated machinery; the output was 50 lamps per day. Better equipment was soon installed and the quality of lamps produced was improved. By 1935 the *Bengal Electric Works Ltd.* was producing vacuum lamps (up to 60 watts) and gas-filled lamps (up to 100 watts) satisfying B. S. Specifications. Later, the

Company took up the production of general lighting service lamps up to 300 watts, street lighting service lamps, and train lighting lamps. Two other companies were incorporated in 1932, viz. *Bharat Electric Bulb Works Ltd.*, Calcutta and *India Electric Lamp Manufacturing Co. Ltd.*, Calcutta. The *Electric Lamp Manufacturers (India) Ltd. (ELMI)*, Calcutta was established in 1935; this firm manufactures lamps according to the requirements of its partner firms, viz. *Philips Electrical Company (India) Ltd.*, *Associated Electrical Industries (India) Ltd.*, *General Electric Company of India Ltd.*, *Greaves Cotton & Crompton Parkinson Ltd.*, *Balmer Lawrie & Co. Ltd.*, and *Siemens Brothers & Co., Ltd.* Other factories established before the war were *Bijlee Products (India) Ltd.*, Bombay, *Mysore Lamp Works Ltd.*, Bangalore, *Calcutta Electrical Lamp Works Ltd.*, Calcutta, *Asia Electrical Lamp Works Ltd.*, Calcutta, and *Radio Lamp Works Ltd.*, Karachi.

The outbreak of World War II gave a fillip to the industry. Existing factories stepped up their production capacities and new factories—*Lux Lamp Ltd.*, Calcutta and *Pradip Lamp Works Ltd.*, Patna—came into existence. The annual total production capacity was 14.5 million lamps in 1945. The *Bijlee Products (India) Ltd.* and *Lux Lamp Ltd.* ceased production after the war; the former, however, has started production again. The *Radio Lamp Works Ltd.* was shifted to Shikohabad in 1948 and another factory was established in 1948. The total capacity in 1949 was 18 million lamps per year.

Inclusive of the *Osler Electric Lamp Manufacturing Co. Ltd.*, Bombay, which has come into production recently, there are now altogether 11

factories in India manufacturing electric lamps with an annual rated capacity of 26 million lamps. Six of these are situated in and around Calcutta, two in Bombay, one in U.P., one in Bihar, and one in Mysore. In addition, two companies, one in Bombay (*National Electrical Lamps Ltd.*) and one in Madras (*Madras Electrical Industries*) have plans to establish factories for the production of lamps. Table 58 gives a list of lamp manufacturers.

Four factories—the *East India Traders*, New Delhi, *P. Saran & Co.*, Delhi, *Natvarlal S. Talati*, Bombay, and *Indus Export-Import*, Bombay—are being set up for the production of miniature lamps with a total annual capacity of 12.5 million lamps. Messrs. *Pradip Lamp Works* have plans to step up the production of miniature lamps to 6 millions per year. In addition, the *Mysore Lamp Works Ltd.*, the *Bengal Electric Lamp Works Ltd.*, and the *Bharat Electric Bulb Works Ltd.* are reported to have schemes for producing miniature lamps; the total capacity when these schemes are implemented will be c. 9 million pieces. Recently, the *Radio Lamp Works*, Shikohabad, now called *Hind Lamps Ltd.*, under a link-up scheme with a group of foreign manufactures, have plans for the production of an additional 3 million lamps.

Raw materials

The electric lamp consists of the following parts: the bulb, the stem or the foot, the filament, and the cap. The stem on which the filament is mounted consists of a flanged tube, a rod, and an exhaust tube, all of glass, and metal electrodes. The raw materials required for the manufacture of electric lamps are: glass bulbs or shells, glass tubings and rods, tungsten wire, molybdenum wire,

TABLE 58—MANUFACTURERS OF ELECTRIC LAMPS

| | Paid up capital (Rs.) | Annual production capacity (no.) | Labour employed |
|--|-----------------------------|---|--------------------|
| <i>Bengal Electric Lamp Works Ltd.</i> , Calcutta | 16,45,536 | 6,000,000 | 509 |
| <i>Electric Lamp Manufacturers of India Ltd. (ELMI)</i> , Calcutta | 10,00,000 | 6,000,000* | 300 |
| <i>Bharat Electrical Industries Ltd.</i> , Calcutta | 3,33,947 | 3,900,000 | 173 |
| <i>Calcutta Electrical Lamp Works Ltd.</i> , Calcutta | 2,00,000 | 600,000 | 50 |
| <i>Asia Electrical Lamp Works Ltd.</i> , Calcutta | 49,200 | 300,000 | 30 |
| <i>Bharat Electric Bulb Works Ltd.</i> , Calcutta | 45,900 | 250,000 | 17 |
| <i>Radio Lamp Works Ltd.</i> , Shikohabad | 29,08,818 | 3,500,000† | 112 |
| <i>Pradip Lamp Works Ltd.</i> , Patna | 10,00,000 | 2,500,000 | 35 |
| <i>Mysore Lamp Works Ltd.</i> , Bangalore | 10,00,000 | 2,500,000 | 35 |
| <i>Bijlee Products (India), Ltd.</i> , Bombay | 1,00,000 | 500,000 | 35 |
| <i>Osler Electrical Lamp Manufacturing Co. Ltd.</i> , Bombay | 62,50,000 | 6,000,000 | 230 |
| <i>National Electrical Lamps, Ltd.</i> , Bombay | n.a. | n.a. | n.a. |
| <i>Madras Electrical Industries</i> , Madras | n.a. | 1,500,000 | n.a. |

n.a. not available

* + 2-3 million special lamps

† expected to increase to 6,000,000

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lead-in wire, mandril wire, brass caps, capping cement, and inert gases (nitrogen and argon).

Glass components—The glass bulb or shell constitutes c. 80% of the bulk of the raw materials. The glass required for the bulb should fuse readily at moderate temperatures without excessive wastage; it should be adaptable to mechanical methods of production; it should fit the lamp base and give a close fused joint under flame heating; it should be clear, should not devitrify or discolour when exposed to the flame, and it should be resistant to moist heat.

The high operating temperatures attainable with gas-filled lamps, as compared with vacuum lamps, greatly increase the brightness of the filament. The glare is avoided by screening or diffusion. Pearl finishing, imparted by internal frosting, reduces the brightness of a 100-watt lamp from 550 stilb (candles/sq. cm.) to 9 stilb with negligible light loss (1–15%). Internal frosting also assists in "softening" the shadows.

Opal glass bulbs reduce lamp brightness to c. 2 stilb. The light loss usually exceeds 10% (Molloy, 129).

Coloured lamps are made by coating the outer or inner surfaces, enamelling, or by employing coloured glasses. Lamps coated outside are suitable for interior use. Enamelled lamps are suitable for outdoor use; they give diffused light with a loss up to c. 20% in light transmission. Coloured glasses are employed wherever purity and permanence of colour are desired (Phillips, 318).

The manufacture of glass shells for electric lamps was first undertaken in India by *Bengal Electric Lamp Works Ltd.* in 1938. Subsequently, *Radio Lamp Works Ltd.*, Shikohabad and *ELMI*, Calcutta started production and the three factories together have an installed annual capacity of 22 million glass shells. Actual production during 1950 was 14 million shells (Table 59). About 16 million shells are annually imported into India, mainly from U.S.A., U.K., and Holland.

Lead glass is used for the manufacture of glass shells. It can be worked over a wide temperature range and is well adapted for manual blowing which is the method used in Indian factories. Lime glass, with a narrow temperature range, is used in U.S.A. for shell production in automatic machines. Lime glass is softer than lead glass and melts more rapidly.

The size of the shell varies with the rating of the lamp: 50 mm. for 5 C.P. and train lighting; 55 mm. for 10, 15, and 20 watts; 60 mm. for 25, 30, and 40 watts; 65 mm. for 60 watts; 70 mm. for 75 watts; 75 mm. for 100 watts; 80 mm. for 150 watts; 90 mm. for 200 watts; 110 mm. for 300 watts; and 130 mm. for 500 watts. Lamps higher than 500 watts are not manufactured in India. Table 60 gives the overall lengths of shells according to B.S.S. No. 161:1940.

TABLE 59—PRODUCTION OF GLASS SHELLS IN 1950*

| | Output | |
|---|-----------|--------|
| | (no.) | (tons) |
| <i>Radio Lamp Works Ltd.</i> , Shikohabad | 3,177,465 | 176 |
| <i>ELMI</i> , Calcutta | 8,852,971 | 242 |
| <i>Bengal Electric Lamp Works Ltd.</i> , Calcutta | 926,845 | 165.5 |

* Information from the *Federation of Glass Manufacturers*

TABLE 60—LENGTHS OF GLASS SHELLS

| Volts | cm. |
|-------|-------------|
| 15 | 92.5 ± 3.5 |
| 25 | 100.0 ± 3.5 |
| 40 | 110.0 ± 3.5 |
| 60 | 117.5 ± 3.5 |
| 75 | 125.0 ± 3.5 |
| 100 | 137.5 ± 3.5 |
| 150 | 160.0 ± 4.5 |
| 200 | 173.0 ± 5.5 |
| 300 | 233.0 ± 7.0 |
| 500 | 267.0 ± 8.0 |

The glass for the inner components of the lamp, such as flange, rod, and exhaust tube, should have a low softening point. In the production of lamps, heat is applied externally for fusing the flanged stem tube to the bulb neck. The bulb becomes hot and the glass selected for the inner components should have a low softening point so that both glasses soften at the same time. The mounted foot is made of lead glass with the same coefficient of expansion as that of the metal wire passed through it. The glass used for the base must satisfy rigid requirements regarding conductivity to obviate discoloration ("lead trees") at the negative pole and fine cracks at the positive pole in d.c. lamps. [Smelt, *Philips tech. Rev.*, 1937, 2 (3), 87].

Tubes of lead glass are employed for the exhaust and the flanges (exhaust tubes, 3.5–4.0 mm. in diam.; flange tubes, 10.5–12.0 mm. in diam.). Rods and tubes of the required specifications are not produced in India at present. Equipment for drawing tubes and rods have been installed at Kundra (Seraikella) and attempts are being made to make the industry self-sufficient with respect to these requirements.

Filament materials—Tungsten, molybdenum, lead-in, and steel mandril wires are imported from Germany, Holland, U.S.A., and Japan. Tungsten wire is used as filament on account of its high melting point (3,600°K), great mechanical strength, appreciable selectivity of radiation in the visible part of the spectrum, and relatively low volatility at high temperatures. It has sufficient strength, both in hot and cold states, to serve as a satisfactory filament when drawn



Bengal Electric Lamp Works Ltd., Calcutta

FIG. 38—SHELL BLOWING DEPARTMENT

out to diameters as small as 0.0005 inch. Pure tungsten filament tends to crystallize when heated and becomes weak and brittle. Crystallization can be prevented by the addition of thorium oxide. For preparing the filament, tungsten rod, prepared by the powder metallurgy technique, is heated in a hydrogen atmosphere to the melting temperature. The rod is hot-worked and drawn at a temperature of 450–650° first through steel and then through diamond dies until a filament of the required diameter (0.02–0.2 mm.) is obtained. Filaments for gas-filled lamps are prepared from tungsten with an admixture of silica (0.4%) and potassium and sodium chlorides (0.4%). In the process of recrystallization the filaments acquire a long-crystal structure and individual crystals slope along the length of the wire. With crystals located in this way, the filaments have good mechanical strength and they do not change in shape under the weight of the filament (Fedorov, 84).

Coiling—The effective cooling surface of the filament is reduced as a result of coiling and the filament can be operated at high temperatures without affecting the life of the lamp. Further, due to the short overall length of the filament,

fewer supports are required; heat loss is thereby further reduced and a slight saving effected in manufacturing cost. A further result of coiling is to produce a black body effect due to multiple reflection of the radiation within the coil. This increases the brightness of the interior of the coil to about 175% of the exterior. The operating colour temperature of gas-filled lamps varies from 2,740°K to 2,980°K for 100 watt and 1,000 watt lamps respectively, compared with 2,490°K for a 60 watt vacuum lamp (Molloy, 128).

The light efficiency of a gas-filled lamp can be increased by double coiling the filament spiral, the lamps being known as coiled-coil lamps. For coiled-coiling, the primary helix is wound in a continuous length from which it is wound round a secondary molybdenum wire with the help of special coiling machines. The loss of energy due to gas cooling is less in coiled-coil lamps than in single spiral lamps and the efficiency is 20% higher. Due to the greater mass of incandescent metal the output of light is also greater. Coiled-coil filaments are made slightly longer and thicker than single coil filaments for operation at the same temperature.

Filament supports and hooks are made of molybdenum wire, 0.4–0.6 mm. diameter,



Bengal Electric Lamp Works Ltd., Calcutta

FIG. 39—FILAMENT COILING

Lead-in wires are made of Dumet, a composite material of nickel-iron coated by copper, a sheath of brass, and a sheath of copper. It has the same longitudinal coefficient of expansion as glass and good adherence.

Brass caps—The cap provides the contact from the mains to the lead-in wires and serves as a support to the lamp. Brass bayonet caps are generally used for small sized lamps. The mechanical support is provided by 2 pins which are pressed into a brass shell. The two contacts at the top of the cap are connected by soft solder to the lead-in wires, insulated from one another and the shell, and supported by a moulded glass insulator. Large sized lamps are provided with Edison screw caps. The top of the cap has a central sole plate, insulated from the shell, to serve as a terminal for one of the lead-in wires; the other lead-in wire is connected to the shell of the cap. Brass caps used in the Indian lamp industry were being imported from U.K., Germany, and Japan before World War II. The *Radio Lamp Works*, Karachi started production of caps complete with black glass during the war period. The *Radio Lamp Works*, Shikohabad propose to undertake the manufacture of brass caps on a large scale.

Inert gases—The gas employed for filling lamps should satisfy the following requirements: it should be inactive, i.e. it should not act on the filament; the thermal conductivity, specific heat, and density of the gas should be low; it should not dissociate when heated to the temperature of the filament; and it should be of such a nature that the tendency for electrical discharge should be minimum. Nitrogen reacts to a slight extent with tungsten to form tungsten nitride. Argon is favoured for its inertness but as it is a conductor of electricity there is a risk of discharge when it is used alone; in admixture with c. 15% nitrogen, argon provides a satisfactory filling medium. A mixture of krypton and xenon may be used in low-power lamps (up to 100 W); these gases have a lower thermal conductivity than argon and nitrogen; further, as tungsten vapour diffuses slowly in a mixture of krypton and xenon, the life of the lamp is enhanced. Inert gases required for filling lamps are mostly imported (Glazebrook, 381; Fedorov, 85).

Capping cement is imported from U.K. and Holland. A small amount is produced by lamp works in India.

Getters are used for coating filaments to clean up the residual gas during the later stages of exhaustion of the bulb. They consist mainly of red phosphorus, nitrocellulose lacquer, and amyl acetate.

Table 61 gives the requirements of raw materials for the production of 23 million lamps which is the present annual rated capacity of lamp manufacturing concerns in India.

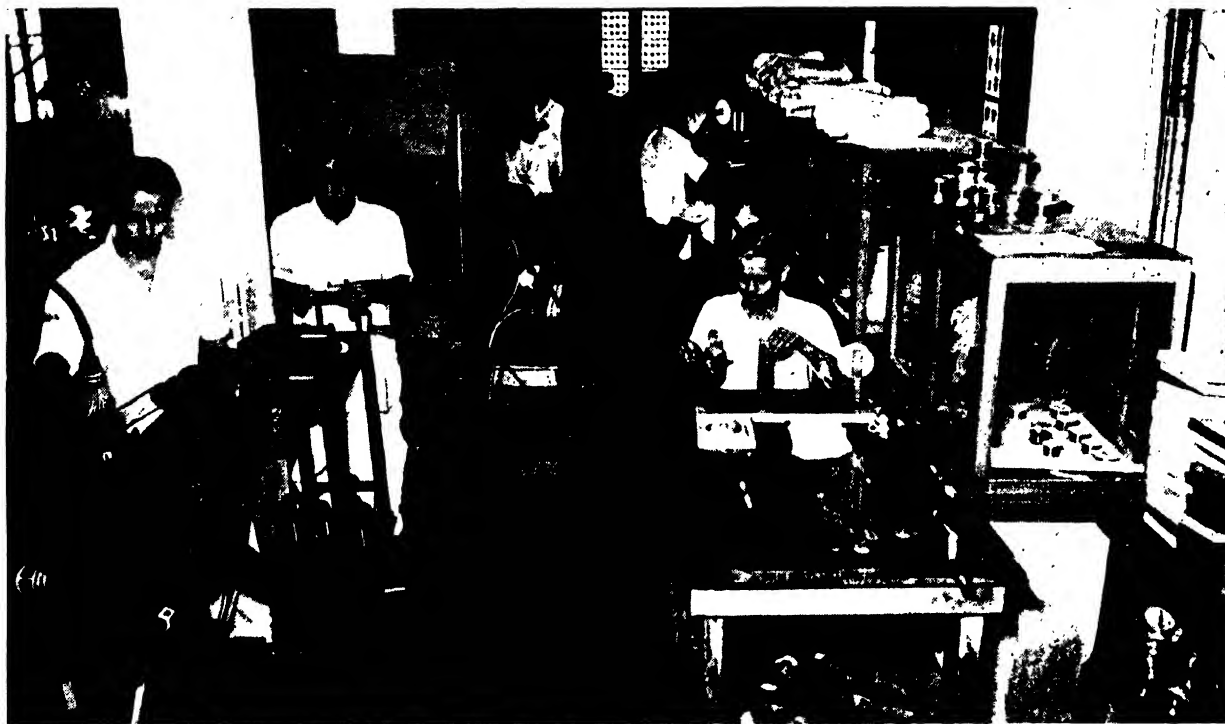
Imports of raw materials and components required in the manufacture of lamps are exempted from duty.

The pre-war and current prices of some of the raw materials are given in Table 62.

TABLE 61—ANNUAL REQUIREMENTS OF RAW MATERIALS*
(for 23 million lamps)

| | Qty | Val. (lakh Rs.) |
|------------------------------------|---------------------|--------------------|
| Glass shells | 26 millions | 26.0 |
| Glass tubings and rods | 270 tons | 9.0 |
| Chemicals | 10 tons | 1.0 |
| Tungsten wire and coiled filaments | 26 million metres | 18.0 |
| Molybdenum wire | 3 million metres | 1.0 |
| Solder wire | | |
| (multi-rosin cored) | 5 tons | 0.3 |
| Argon and nitrogen | 870,000 c. ft. | 8.7 |
| Lead-in wires | 55 million pieces | 2.75 |
| Brass caps | 26.5 million pieces | 10.6 |
| Capping cement | 50 tons | 1.8 |
| Steel mandril wire | 1.0 ton | 0.5 |

* Planning Comm., *Programmes of Industrial Development, 1951-56, 1953, 99*



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FIG. 40—FILAMENT STANDARDIZING DEPARTMENT

TABLE 62—PRICES OF RAW MATERIALS
(In Rs. as.)

| | 1939 | 1951 |
|--|------|-------|
| Glass shells (60 mm. for 40 watts), per 1,000 pieces | 50 0 | 110 0 |
| Caps, per 1,000 pieces | 23 0 | 40 0 |
| Lead-in wires (for 40 watts), per 1,000 pieces | 2 8 | 3 8 |
| Argon, per c. ft. | 1 8 | 3 8 |
| Corrugated packing board (for 40 watts), per 1,000 pieces | 8 4 | 35 0 |

Manufacture

The necks of glass shells as received in the works are cut off by applying flames and the shells washed first with hydrochloric acid and then with water. They are dried and stamped with the maker's brand and seal at 400-500°.

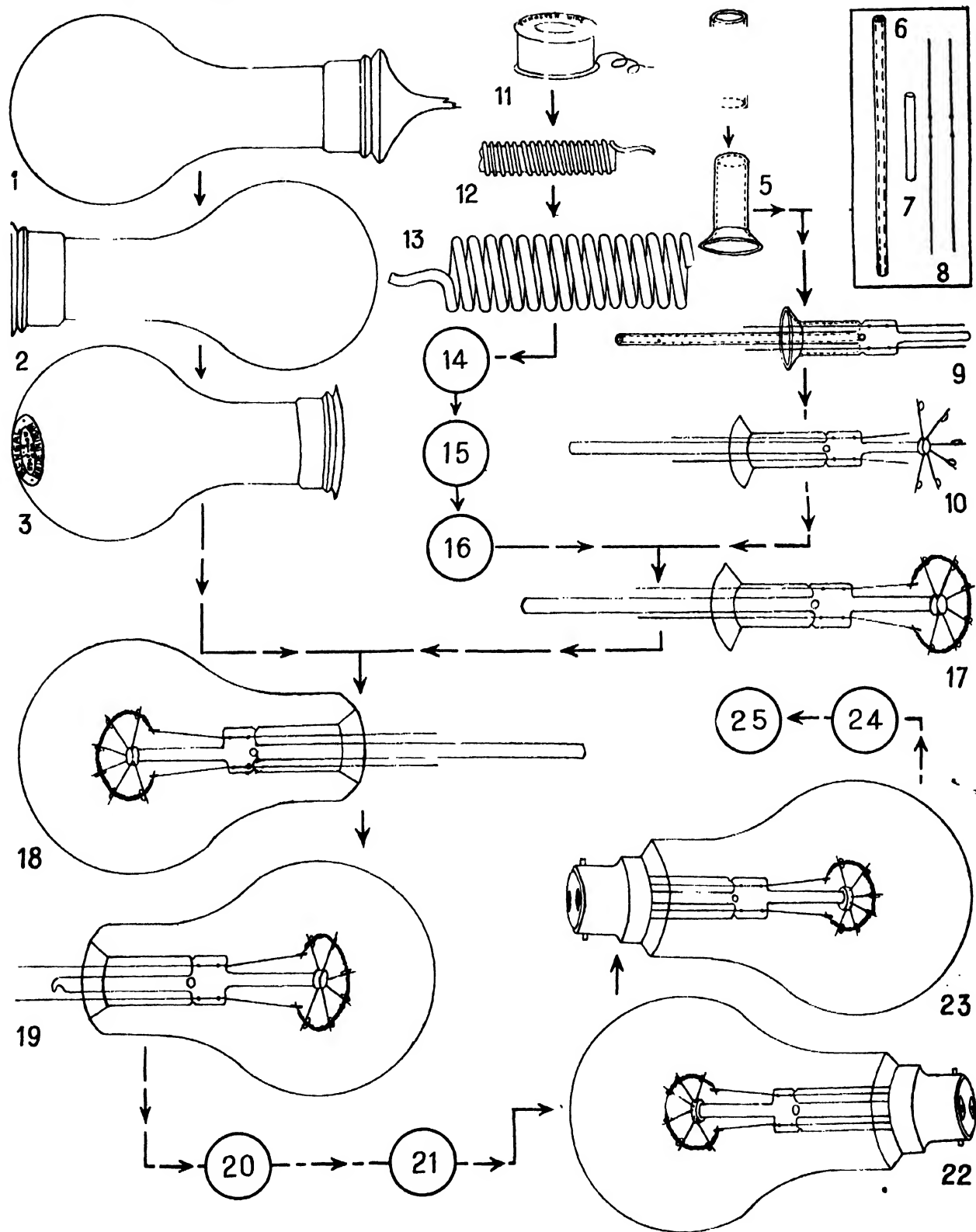
Flange tubes are fed vertically to the flange-making or flare machines and rotated between gas jets; the ends are softened and opened out into flanges and cut to the required size. Exhaust tubes and arbor rods are cut to required lengths.

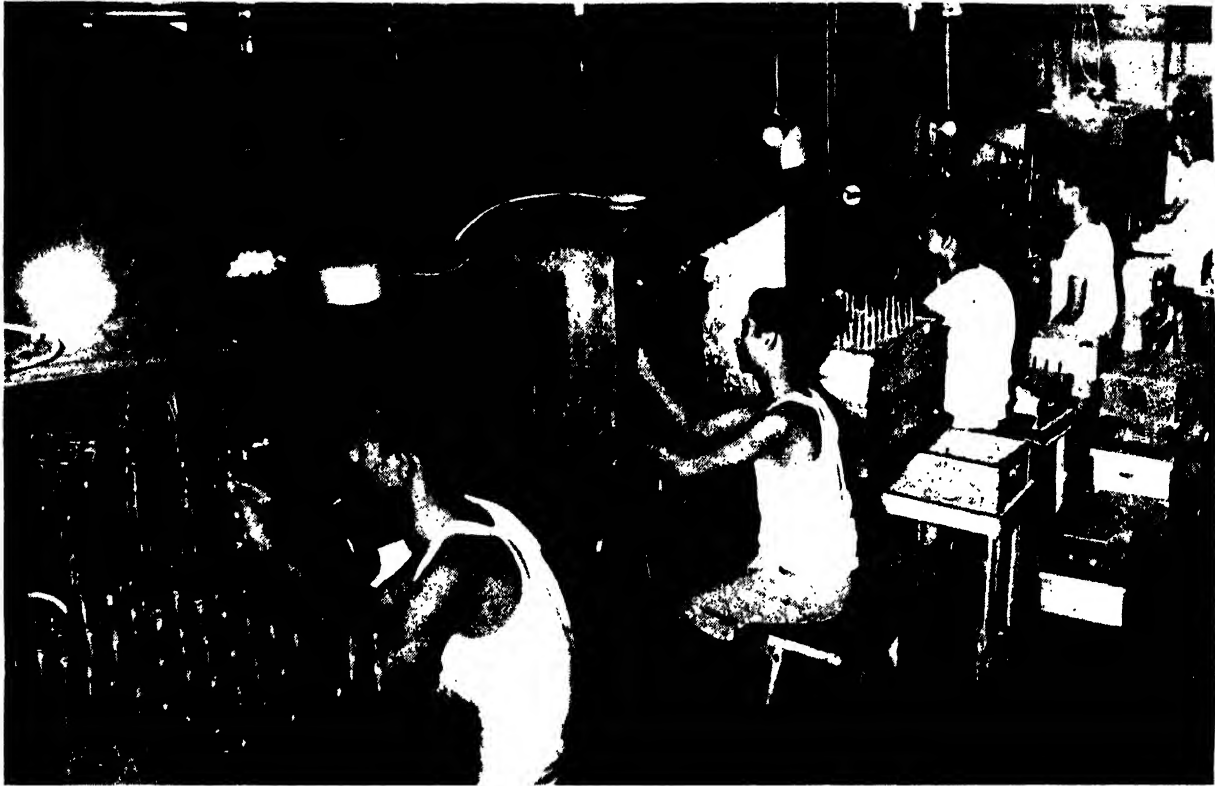
The exhaust tube, the arbor rod, and the lead-in wires are fed to the flanged tube, held in their



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FIG. 41—STFM MAKING DEPARTMENT





Bengal Electric Lamp Works Ltd., Calcutta

FIG. 43—MOLYBDENUM WIRES ARE INSERTED INTO STEMS AND HOOKED

proper relative positions, and pinched together in gas flames. The lower ends of the tubes are softened by flames and squeezed over lead-in wires; the flattened part (pinch) is welded to the glass rod and the inner tube by a pair of pincers. The flanged tube is heated at a point opposite to that at which the exhaust tube is joined to the pinch and compressed air forced through the exhaust tube to blow a hole between it and the outer surface of the flanged tube. The foot is then annealed.

The free end of the arbor rod is softened in a gas flame and pressed into the shape of a button. It

is softened by a pencil burner and molybdenum wires are pushed into it. It is then air-cooled, the wires shaped to hooks and the excess cut off. The foot is now ready to receive the filament.

The ELMI factory obtains the filaments in coiled form. Other factories produce filaments from imported wire by close-winding over a mandril wire of special steel. The coiled wire is cut into proper lengths, immersed in hydrochloric acid to dissolve the mandril, and washed to remove the acid. The coil is treated with diluted caustic soda solution to remove traces of oxide, washed with distilled water, and dried. The length of

FIG. 42—INCANDESCENT ELECTRIC LAMP : FROM THE RAW MATERIAL TO THE FINISHED PRODUCT

(1) GLASS SHELL AS RECEIVED IN THE WORKS; (2) NECK CUT, SHELL WASHED, AND DRIED; (3) SHELL STAMPED WITH MAKER'S BRAND AND SEAL; (4) FLANGE TUBE; (5) SAME TUBE AFTER FLANGING; (6) EXHAUST TUBE; (7) ARBOR ROD; (8) TRIMETALLIC ELECTRODES OF NICKEL, COPPER, AND COPPER-CLAD NICKEL IRON; (9) FOOT COMPRISING FLANGED TUBE, ARBOR ROD, AND LEAD-IN WIRES; (10) FREE END OF ARBOR ROD HUBBED AND MOLYBDENUM WIRES INSERTED; THE WIRES ARE CUT TO PROPER SIZE AND ENDS HOOKED FOR SUPPORTING FILAMENT; (11) FILAMENT WIRE; (12) SPIRALLED FILAMENT PREPARED BY CLOSE-WINDING OVER A MANDRIL WIRE OF SPECIAL STEEL; (13) SPIRALLED WIRE CUT TO PROPER LENGTH, MANDRIL DISSOLVED OUT, AND WASHED; (14) LENGTH OF SPIRALLED FILAMENT CHECKED BY WEIGHING IN A TORSION BALANCE; (15) FILAMENT CHECKED FOR FRINGING BY INSPECTION OF MAGNIFIED

IMAGE; (16) FILAMENT HEATED IN AN ELECTRIC FURNACE IN A HYDROGEN-NITROGEN ATMOSPHERE; (17) FILAMENT MOUNTED ON SUPPORTS AND ENDS CONNECTED TO LEAD-IN WIRES; (18) FILAMENTED FOOT MOUNTED IN BULB, FLANGED EDGE FUSED TO NECK LEAVING EXHAUST TUBE AND ELECTRODES OUTSIDE; (19) VACUUM CREATED BY EXHAUST PUMPS, INERT GAS (ARGON) INSERTED (IN GAS-FILLED LAMPS), AND EXHAUST TUBE SEALED; (20) VACUUM TESTED BY HIGH FREQUENCY TESTER; (21) LAMP AGED IN AGING RACK AND TESTED; (22) CAP FIXED; (23) PROTRUDING ENDS OF LEAD-IN WIRES CUT AND SOLDERED TO METAL CONTACT PIERCES OVER CAP; (24) PHOTOMETER TEST FOR EFFICIENCY; (25) FINISHED LAMP SUBJECTED TO LIFE AND VIBRATION TESTS AND CAP TO TORSION TEST.

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the wire is checked by weighing in a torsion balance; it is also checked for fringing by visual inspection of a magnified (120-150 times) image of the filament. The filaments are then heated in an electric furnace in an atmosphere containing equal volumes of hydrogen and nitrogen.

The prepared filament is mounted manually on supports and the two ends are pinched to the lead-in wires. The filament, after mounting, is dipped into the getter.

The filamented foot is mounted in the bulb with the help of a machine which places the bulb, with its mouth downwards, over the gettered stem. The flanged edge of the foot is fused to the neck of the bulb by a gas flame while the bulb is rotated to give a perfect joint leaving the exhaust tube and the electrodes outside. Finally, the excess length of the neck is cut off by a pointed flame.

Sealed bulbs are mounted on a rotating machine and as they pass through a heating chamber, they are exhausted by a series of pumps acting through a central exhaust tube. Heating removes occluded gases and ensures a permanent vacuum. Exhausted lamps are sealed off automatically by gas flame burners. The completed lamp is tested for vacuum by a high frequency tester.

In the case of gas-filled lamps, the lamps are exhausted, flashed with nitrogen, filled with a



Bengal Electric Lamp Works Ltd., Calcutta

FIG. 44--PHOTOMETER DEPARTMENT



Bengal Electric Lamp Works Ltd., Calcutta

FIG. 45--LIFE TESTING DEPARTMENT

mixture of argon and nitrogen (85:15), and sealed. The gas mixture is dried by passage through phosphorus pentoxide tubes, heated, and again passed through phosphorus pentoxide tubes before filling.

Sealed lamps are passed to the capping mill. The cap is filled with a special cement and progressively heated as the lamp rotates, thereby baking the cement and fixing it firmly to the bulb. Simultaneously a current is passed through the filament when the getter reacts with the residual gas and combines with it. The protruding ends of the lead-in wires are cut off and soldered to the metal contact pieces over the cap.

The lamp is flashed or aged, first at a voltage lower than the one specified and then for 2 minutes at 20% over-voltage. The degree of vacuum, luminosity, and energy consumption are tested. A few lamps are picked out from the day's output and subjected to life and vibration

TABLE 63—PRODUCTION OF ELECTRIC LAMPS*

| | Production (no.) |
|------|---------------------|
| 1942 | 2,750,000 |
| 1943 | 3,750,000 |
| 1944 | 3,750,000 |
| 1946 | 8,114,575 |
| 1947 | 7,620,000 |
| 1948 | 9,246,350 |
| 1949 | 13,640,788 |
| 1950 | 14,307,058 |
| 1951 | 15,522,550 |
| 1952 | 20,881,831 |

Total production, according to the *Indian Lamp Factories Association*, was 14,395,232 lamps in 1950; 15,461,743 in 1951; and 19,551,102 in 1952

* *Monthly Statistics of the Production of Selected Industries of India*, Directorate of Industrial Statistics, Calcutta, Minist. Comm. & Industr., Govt. of India

TABLE 64—PRODUCTION OF ELECTRIC LAMPS BY DIFFERENT FACTORIES*
(Qty in numbers)

| | 1950 | 1951 | 1952 |
|--|------------|------------|------------|
| Asia Electrical Lamp Works Ltd., Calcutta | 179,581 | 221,804 | 245,081 |
| Bengal Electric Lamp Works Ltd., Calcutta | 3,271,683 | 2,651,282 | 3,779,654 |
| Bharat Electric Bulb Works Ltd., Calcutta | 99,549 | 47,863 | 40,786 |
| Bharat Electrical Industries Ltd., Calcutta | 1,091,929 | 1,141,828 | 1,121,872 |
| Rijlee Products (India) Ltd., Bombay | 300,237 | 329,841 | 333,803 |
| Calcutta Electrical Lamp Works Ltd., Calcutta | 271,751 | 294,830 | 244,440 |
| Electric Lamp Manufacturers (India) Ltd., Calcutta | 6,102,635 | 6,797,396 | 8,552,510 |
| Mysore Lamp Works Ltd., Bangalore | 1,053,383 | 1,355,510 | 1,264,546 |
| Pradip Lamp Works Ltd., Patna | 247,448 | 151,950 | 256,856 |
| Radio Lamp Works Ltd., Shikohabad | 1,777,036 | 2,469,439 | 3,711,554 |
| Total | 14,395,232 | 15,461,743 | 19,551,102 |

* Information from the *Indian Lamp Factories Association*, Calcutta

tests. Caps are subjected to torsion tests. Tested lamps are packed in cardboard cartons.

Specifications

Lamps are produced to B. S. Specifications No. 161 (for general lighting service) and No. 555 (for train lighting). The standard defines voltage and power; it defines also the light efficiency (lm/W) and lamp life. The life of a lamp is defined as the time it takes to burn out or the time required for the luminous flux to diminish by not more than 20% of the initial value. For lighting lamps, the standard specifies a life of 1,000 hr. Values of light efficiency are given for a life of 1,000 hr.

Production

Except the *ELMI*, all other factories produce lamps marketed under their own names. The *ELMI* factory produces Philips, Osram, Mazda,

TABLE 65—IMPORTS OF ELECTRIC LAMPS
(Qty in numbers and val. in Rs.)

| | Gas-filled | | Vacuum | |
|-----------------------|------------|-----------|-----------|-----------|
| | Qty | Val. | Qty | Val. |
| 1934/35-1938/39 (av.) | 2,255,791 | 17,73,013 | 7,886,207 | 14,12,148 |
| 1939/40-1943/44 (av.) | 1,237,595 | 11,12,311 | 5,232,297 | 7,46,199 |
| 1944-45 | 2,262,625 | 21,69,947 | 892,800 | 4,95,551 |
| 1945-46 | 6,152,944 | 75,49,904 | 2,133,753 | 12,36,193 |
| 1946-47 | 2,262,136 | 23,22,940 | 1,576,018 | 6,98,478 |
| 1947-48 | 1,584,387 | 20,47,556 | 3,595,133 | 10,50,491 |
| 1948-49 | 2,268,803 | 26,65,246 | 1,854,238 | 12,91,863 |
| 1949-50 | 3,431,963 | 32,33,742 | 2,502,171 | 12,33,113 |
| 1950-51 | 403,787 | 6,26,529 | 132,271 | 66,848 |
| 1951-52 | 495,922 | 6,87,900 | 87,579 | 48,127 |
| 1952-53 | 305,275 | 3,89,392 | 141,081 | 1,59,611 |

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TABLE 66—IMPORTS OF ELECTRIC INCANDESCENT LAMPS
(Qty in numbers and val. in Rs.)

| | Auto | | Torch | | Other sorts | | Lamp parts and accessories Val. |
|-----------------------|-----------|-----------|------------|-----------|-------------|-------------|---------------------------------|
| | Qty | Val. | Qty | Val. | Qty | Val. | |
| 1934/35-1938/39 (av.) | 1,046,705 | 1,01,843 | 19,724,439 | 18,98,899 | 2,334,664 | 11,10,147 | 9,07,216 |
| 1939/40-1943/44 (av.) | 1,070,990 | 1,12,325 | 21,052,709 | 27,02,881 | 1,166,542 | 4,61,028 | 1,72,504 |
| 1944-45 | 296,037 | 82,895 | 15,849,970 | 11,82,352 | 76,645 | 1,06,022 | 72,371 |
| 1945-46 | 179,440 | 55,351 | 20,393,043 | 21,00,509 | 1,956,818 | 10,60,597 | 1,50,795 |
| 1946-47 | 138,341 | 52,058 | 26,611,609 | 16,51,995 | 4,028,816 | 63,97,268 | 3,91,818 |
| 1947-48 | 847,890 | 4,00,604 | 14,099,953 | 13,21,747 | 3,185,042 | 95,66,146 | 15,35,044 |
| 1948-49 | 3,231,243 | 10,03,738 | 18,915,939 | 21,80,589 | 9,273,702 | 95,33,024 | 31,99,349 |
| 1949-50 | 1,016,825 | 4,52,519 | 6,397,791 | 7,86,908 | 11,413,607 | 1,64,24,436 | 36,87,081 |
| 1950-51 | 822,723 | 4,41,709 | 1,426,115 | 2,26,125 | 1,830,653 | 27,87,984 | 11,48,408 |
| 1951-52 | 9,928,265 | 32,04,714 | 7,775,213 | 1,89,011 | 589,142 | 16,48,315 | 6,92,617 |
| 1952-53 | 5,693,323 | 19,80,537 | 11,824,078 | 2,87,309 | 1,653,280 | 28,80,961 | 9,66,728 |

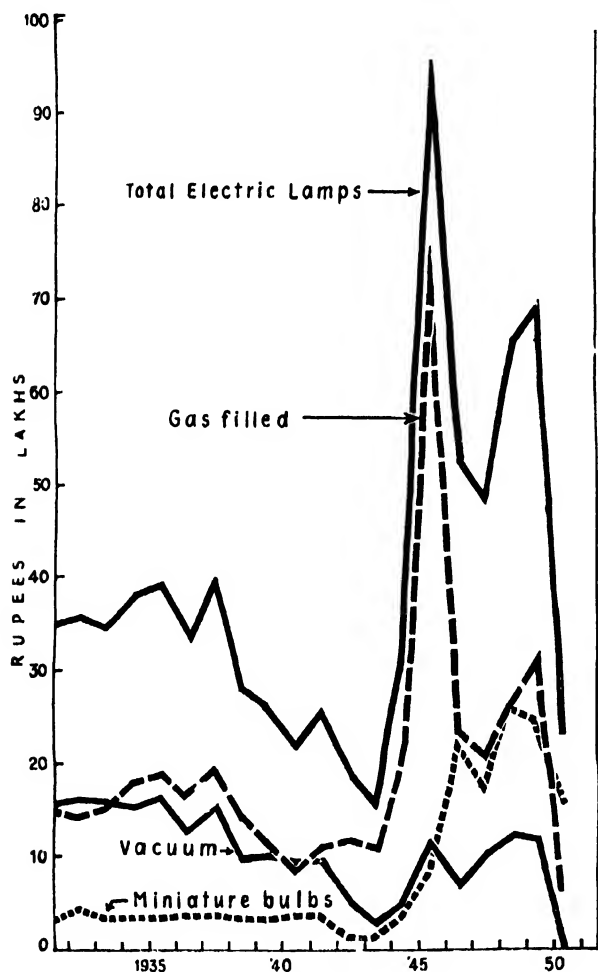


FIG. 46—IMPORTS OF LAMPS

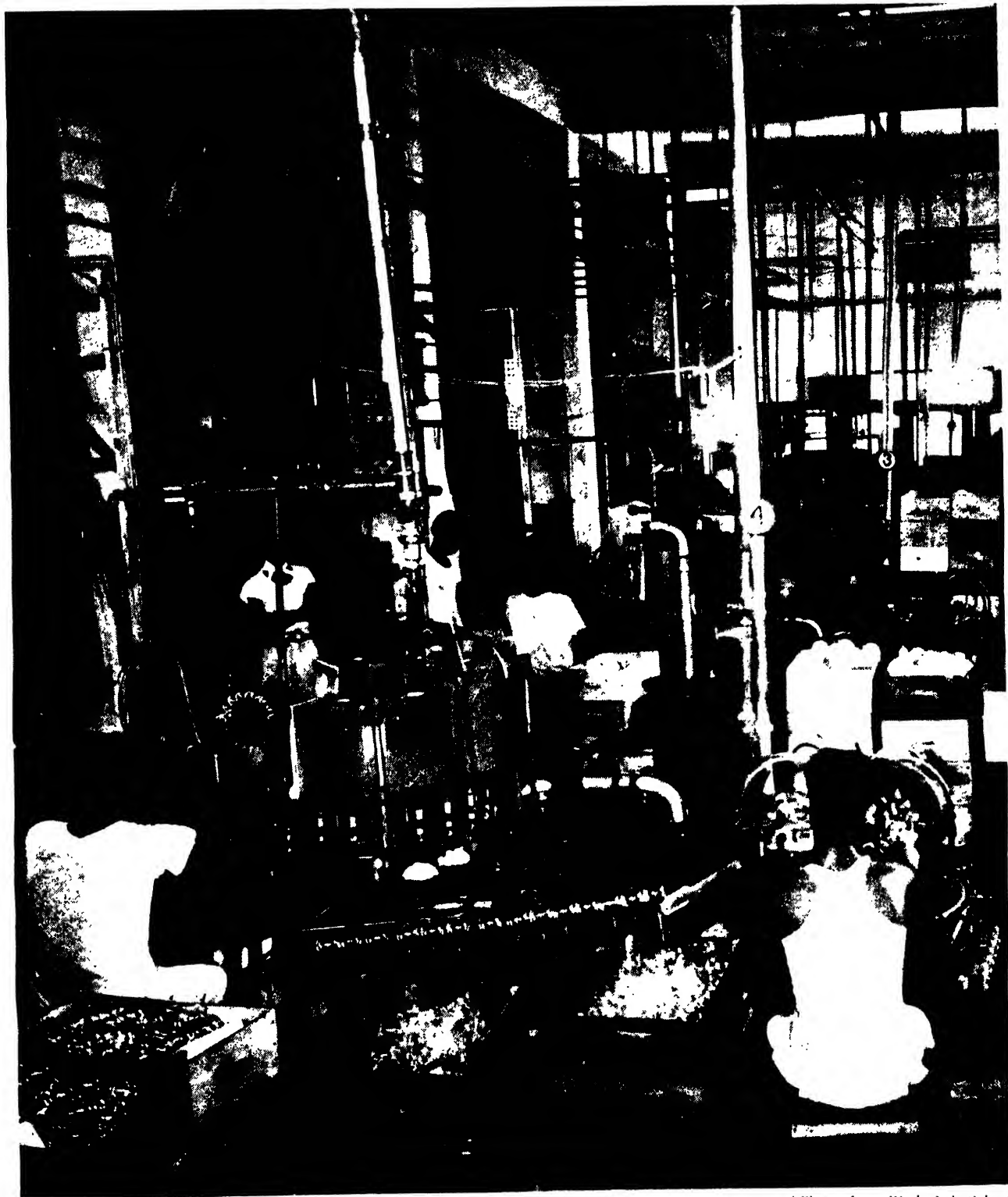
Crompton, Siemens, Royal Ediswan, and Metrovick lamps. The types of lamps produced in India are: (1) general lighting service lamps (vacuum and gas-filled), (2) low voltage lamps, (3) train lighting gas-filled lamps (10-30 watts), and (4) projection lamps. Four factories are being set up for the manufacture of miniature lamps, such as auto lamps, torch lamps, and instrument panel lamps. Vacuum and gas-filled lamps are manufactured in standard voltages—100-120 volts and 220-250 volts. Train lighting lamps are manufactured in 24 and 32 volts. The wattages of lamps produced are: *Vacuum lamps*—5 C.P., 10, 15, 20, 25, 30, 40, and 60 watts; *gas-filled lamps*—40, 60, 75, 100, 150, 200, 300, and 500 watts; and *train lighting lamps*—15, 20, 25, and 30 watts. Table 63 gives the annual production of electric lamps in India. Table 64 gives the production by individual factories in 1950, 1951, 1952, and 1953.

Imports—Tables 65 and 66 give imports of electric lamps into India.

During the quinquennium ending 1938-39, the shares of different countries in the import of lamps were as follows: *gas-filled lamps*—U.K., 51.4; Netherlands, 12.1; and Japan, 10.2%; *vacuum lamps*—Japan, 63.6; Netherlands, 12.1; and U.K., 11.6%; *auto lamps*—Japan, 63.5; U.S.A., 22.2; and Netherlands, 9.5%; and *torch lamps*—Japan, 74.8; and U.S.A., 16.8%.

Tables 67 and 68 give the imports of electric incandescent lamps into India from U.K. and U.S.A. respectively.

The consumption of electric lamps in India in recent years was as follows: 1948-49, 14.47 millions; 1949-50, 19.91 millions; and 1950-51, 14.68 millions. The Planning Commission estimates the requirements of general lighting service lamps in 1955-56 at 30 millions.



Messrs. Bengal Electric Lamp Works Ltd., Calcutta

SEALING AND GAS-FILLING OF ELECTRIC LAMPS

TABLE 67—IMPORTS OF ELECTRIC INCANDESCENT LAMPS FROM U.K.
(Qty in numbers and val. in £)

| | Qty | | | | Val. | | | |
|--|-----------|-----------|-----------|---------|--------|--------|---------|--------|
| | 1947 | 1948 | 1949 | 1950 | 1947 | 1948 | 1949 | 1950 |
| Bulbs complete, not exceeding 24 volts, motor vehicle type | 31,652 | 133,844 | 132,430 | 171,611 | 7,841 | 4,277 | 6,820 | 8,192 |
| Bulbs, not exceeding 24 volts, flashlight, radio panel, & cycle dynamo types | 1,682,179 | 982,996 | 2,552,222 | 416,963 | 17,897 | 11,353 | 31,585 | 4,703 |
| Other bulbs, not exceeding 24 volts | 275,749 | 66,246 | 581,034 | 82,696 | 8,549 | 4,396 | 26,719 | 4,932 |
| Bulbs, exceeding 24 volts | 1,591,621 | 1,611,981 | 3,214,545 | 404,586 | 77,782 | 75,082 | 141,729 | 19,962 |

TABLE 68—IMPORTS OF ELECTRIC INCANDESCENT LAMPS FROM U.S.A.
(Qty in numbers and val. in \$)

| | 1948 | | 1949 | | 1950 | | 1951 | |
|---------------------------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|
| | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. |
| Incandescent lamps, small | 2,625,135 | 174,216 | 5,871,467 | 266,520 | 2,156,750 | 120,707 | 7,674,242 | 522,249 |
| Incandescent lamps, large | 184,733 | 24,534 | 104,628 | 19,759 | 135,820 | 3,840 | 356,070 | 34,322 |

DISCHARGE LAMPS

The luminous glow accompanying the discharge of electricity through rarefied gases has been utilized in the development of discharge lamps. Incandescent lamps are now supplemented, and to some extent superseded, by discharge lamps.

The discharge lamp consists of an enclosed glass or quartz container with metal electrodes containing a gas or metallic vapour or both. When the tube is connected to the power supply, ionization takes place due to the collision between gas or vapour molecules and high speed electrons, as a result of which some of the electrons in the atoms are excited to higher states; light is produced if the radiation due to the return of an excited electron to the lower excited states or to the ground state lies in the visible region. With increase in ionization, the current density increases rapidly and a resistance is inserted in the circuit to limit and thereby stabilize the current.

The radiation from a low pressure discharge lamp consists of a number of monochromatic lines. If only a few of them lie in the visible region and at least one of them is a resonance line, the luminous efficiency would still be high as in sodium discharge lamps. The efficiency will also be high if a part of the visible radiation is due to the existence of metastable states, as in neon and low-pressure mercury lamps, in which the visible light is due mostly to the transition of excited electrons to metastable states. The visible spectrum of a neon lamp consists of a large number of lines crowded together in the red region, giving a continuous band. In the low-

pressure mercury vapour lamp there are only 2 strong lines—green and violet—in the visible region; the radiation is predominantly ultra-violet.

The narrow spectrum of a low-pressure mercury vapour lamp can be changed to a somewhat continuous spectrum over the visible region by increasing the vapour pressure. As the vapour pressure in the tube is increased, the distance between the electrodes remaining the same, the arc voltage has to be increased to obtain discharge; if the arc voltage is kept constant, the distance between the electrodes has to be decreased, as a result of which both volts per cm. and watts per cm. increase. The collisions occur with great violence and the percentage of higher excited states increases and more lines, not seen in low pressure discharge, are seen in the spectrum. The relative intensity of radiations changes with increase in pressure. At high pressure, the resonance radiation tends to be absorbed in the arc and it disappears when the pressure reaches c. 10 atm. This absorption raises the electrons to higher excited states and the luminous efficiency of the discharge increases. Also, at high pressure, molecular radiation comes into effect and changes the relative strengths of the lines, broadens the spectrum, and increases the red radiation.

In sodium vapour and mercury vapour lamps, a trace of an inert gas, usually argon or neon, is inserted at low-pressure to assist the initiation of the discharge.

Discharge lamps are either of the cold cathode

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type or the hot cathode type. In the former the potential drop at the cathode due to the space charge in the gas is high (100–200 volts). The electrodes (iron, nickel, or iron alloy) are of considerable dimensions in relation to the tube and are of cylindrical shape. Electrons are emitted from the cathode due to the bombardment of positive ions. The optimum pressure for bombardment in the neon lamp is about 1 mm. of mercury; a lower pressure will induce sputtering and ejected particles from the cathode combine with gas molecules and deposit on the walls of the lamp, a phenomenon known as 'hardening'.

Hot cathode lamps are operated on mains voltage. The cathodes are coated with active (thermionic) materials and heated either by the discharge itself or by an external source. The additional electron flow neutralizes the space charge and reduces the cathode fall to c. 15 volts, as a result of which the loss of energy at the cathode is reduced and the current density is high.

The more important discharge lamps available in the market are sodium vapour lamps, medium and high pressure mercury vapour lamps, fluorescent tubes, neon signs, and neon glow lamps. Of these, only fluorescent tubes and neon signs are manufactured in India. Sodium vapour lamps, medium and high pressure mercury vapour lamps, and the bulk of fluorescent lamps are of the cold cathode type.

Sodium lamps—The common sodium discharge lamp consists of a U-tube of resistant glass containing metallic sodium and neon at low pressure enclosed in a vacuum jacket of heat-resistant glass. An activated electrode is sealed into each end of the tube. The normal mains voltage is not sufficient to initiate the discharge and a leak transformer providing an open circuit voltage of c. 480 volts is therefore employed. Neon is added to give sufficient heat to vaporize the cold sodium in the beginning and to provide sufficient electrical conductivity to the very low partial pressure of the sodium vapours. The initial discharge through the inert gas heats the tube and vaporizes the sodium and the discharge changes from neon red to monochromatic sodium yellow (5,890 and 5,896 Å). The full light output is obtained after 10–15 minutes. After the arc is struck, the transformer acts as a ballast in the circuit for stabilizing the discharge. Sodium lamps are made in ratings of 45, 60, 85, and 140 watts; the 140 watt lamp has the highest luminous efficiency (c. 54.5 lm/W) among discharge lamps used for general lighting purposes (Hewitt, 66).

Sodium lamps are used mainly for street lighting; night driving of automobiles is almost as safe under sodium lamp illumination as in daylight. Sodium lamps are used for lighting railway shunting and marshalling yards, factory grounds, quays, wharves, locks, canals, air fields, assembly

shops, foundries, engineering works, and glass factories. They are also useful for photographic printing and enlarging on chloride paper. Piesing effects are obtained by floodlighting with sodium lamps (Funke, 67).

Medium pressure mercury lamps—Medium pressure mercury lamps operate at $\frac{1}{2}$ –1 atm. vapour pressure. They consist of tubes containing mercury and argon at low pressure, the latter being added to assist in starting owing to its low ionization potential. The lamp is shielded by an evacuated outer glass envelope and the vapour pressure inside the tube is not affected by temperature variations. Activated electrodes (short rods of alkaline earth oxide held in tungsten wire coils) are fitted at the ends. An auxiliary electrode, in the form of a fine wire, is sealed in the tube close to one of the main electrodes and is connected through a resistance of c. 50,000 ohms to the remote main electrode in order to limit the current in the starting spark. The two connections from the tube are brought to the lamp cap. The ends of the tube are silvered to reduce heat radiation from the electrode. A choke ballast is employed to stabilize the main current. The lamps are placed vertically with the caps up.

When the lamp is switched on, the potential gradient between the auxiliary electrode and the adjacent main electrode initiates a pale blue glow discharge in the argon across the short space, the whole cross section of the tube being filled with the positive column. The glow discharge causes emission of electrons from the main electrodes and also vaporizes the mercury, resulting in a gradual rise of pressure until a discharge is induced in the mercury vapour between the main electrodes. The low resistance automatically cuts out the auxiliary electrode. The full light output is obtained in about 6 minutes after the start.

The initial arc voltage is c. 20 volts and the final value, c. 120 volts. During the running-up, the energy and the specific loading in watts per cc. increase considerably. The final arc has a brightness of about 150 candles/sq. cm. (Clarke, 130).

The chief radiations in the visible spectrum of the discharge are 4,047 Å in the violet region, 4,358 Å in the violet/indigo region, 5,461 Å in the yellow/green region, and 5,770/5,790 Å in the yellow region. The colour is blue-green with a marked deficiency in red. The colour rendering of objects seen under this light is suitable for blues, greens, and yellows; reds appear dull brown (Hewitt, 58).

Medium pressure mercury lamps are standardized in three sizes, viz. 250, 400, and 650 watts. They are used mainly for street lighting. They are also used for floodlighting of buildings.

The colour deficiency of medium pressure

mercury lamps can be improved by (1) the introduction of cadmium in the form of an amalgam with mercury, (2) the use of fluorescent materials, or by (3) combination with tungsten lighting.

High pressure mercury lamps—A quartz tube with an outer glass envelope is employed in the high pressure mercury lamp. An auxiliary electrode is used for starting the arc. The brightness is high and the inside wall of the outer glass envelope is therefore usually pearled for reducing the brightness. The lamp is operated at a pressure of c. 10 atm. when fully run-up and it reaches the full luminous output in 3 minutes. High pressure mercury lamps are made in 80 and 125-watt sizes. They are widely used for industrial and street lighting.

The 'high brightness' mercury lamp is made in the form of a spherical quartz bulb, and a 'foil seal' is used as electrode seal on account of the extremely low thermal expansion of quartz. It operates at a vapour pressure of c. 20 atm. and the spectrum is continuous over a considerable range. The specific loading is high: a 500 watt lamp has an arc length of 0.5 cm. and an arc voltage at normal operation of 70 volts; the volts per cm. and watts per cm. are 140 and 1,000 respectively (Clarke, 136).

Colour modified high pressure lamps operate at a vapour pressure of c. 25 atm. Cadmium or a combination of cadmium and zinc is employed along with mercury to make up the deficiency in the red and other regions, the resulting light being almost identical with that of the high power carbon arc. The lamps are suitable for film projection, television, and film studio lighting (Clarke, 141).

Water-cooled high pressure mercury lamps are operated at a vapour pressure of 75 atm. and above. They are in the form of thick-walled capillary quartz tubes. The brightness is 30,000 stilb at a pressure of 75 atm. and 60,000 stilb at 115 atm.

Fluorescent lamps—A recent development in light sources is the tubular fluorescent lamp in which the ultraviolet radiation of low-pressure mercury vapour discharge is converted into visible light by the fluorescent coating on the inside wall of the tube. The $2,537\text{\AA}$ mercury line is particularly prominent in low-pressure mercury vapour discharge and it reaches its maximum intensity when the vapour pressure is c. 0.005 mm. of mercury. By the use of a fluorescent coating on the walls of the lamp, this radiation can be utilized to produce light with a continuous spectral distribution. The luminous flux is proportional to the magnitude of the irradiation.

The advantages of fluorescent lamps over other forms of discharge lamps are: (1) shadow effects are reduced due to the longer lengths of the lamps,

(2) the emitted light has daylight characters, and (3) low brightness (Miller, 12).

Fluorescent lamps of the hot cathode type are manufactured in a number of sizes. The usual tubes are 60, 48, 24, and 18 inches in length, the respective wattages being 80, 40, 20, and 15. The 80 watt lamp is 5 ft. long and $1\frac{1}{2}$ inches in diam. Coiled-coil filament electrodes, coated with an electron-emission mixture of alkaline earth oxides are sealed, one at each end of the tube. Each electrode is fitted with one or two heavy wire anodes placed on either side of the coil. The tube is filled with argon at low pressure and a small amount of mercury is introduced into the tube.

The fluorescent coating or 'phosphor' is applied to the inside wall of the tube. It consists of calcium-fluoro-chloro-phosphates mixed with different activators to produce lights of various colours. The coating should be sufficient to absorb the $2,537\text{\AA}$ radiation and transparent enough to transmit light. The phosphor is mixed with an organic resin base and applied to the tube. The base is later removed by baking the tube at $400\text{--}500^\circ$. The lamp is connected in series with a choke ballast for operation on a.c. supplies and with resistance ballast for d.c. supplies.

A fluorescent tube is provided with a starter switch. It allows current to flow through the two electrodes in series for 1–2 sec. to preheat them, and then automatically breaks the circuit, thus causing a momentary inductive surge of voltage which strikes the discharge in argon; this in turn establishes the discharge in mercury vapour.

Fluorescent lamps have low power consumption, low brightness, good colour rendering properties, and long life. They are used extensively for interior lighting in industrial and commercial establishments and to a certain extent for street lighting.

Mercury vapour fluorescent tubes with cold cathodes have been recently developed. The electrodes are in the form of iron or nickel cylinders, about 2 in. long, and have large emission surface areas. The voltage drop at the electrodes is considerable and long tubes of narrow diameter are employed. The standard lamp is 80 ft. 6 in. long \times 20 mm. diam. and rated 70 watts with a lamp current of 120 milliamp. The tubes are bent into various shapes for decorative purposes. They are operated on high voltage and have been widely employed for decorative lighting. The voltage required for starting and maintaining the discharge is provided by a step-up transformer, which also dispenses with the need for a choke. Unlike hot cathode fluorescent tubes there is no delay in starting. The life of the lamp is c. 10,000 hours as compared to 5,000 hours for a 80-watt hot cathode tube. Cold cathode fluorescent tubes are sometimes filled with neon in place of mercury

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TABLE 69—IMPORTS OF DISCHARGE LAMPS FROM U.K.
(Qty in numbers and val. in £)

| | Qty | | | | Val. | | | |
|---|--------|--------|--------|--------|--------|--------|--------|--------|
| | 1947 | 1948 | 1949 | 1950 | 1947 | 1948 | 1949 | 1950 |
| Fluorescent tubular lamps of all types other than high tension for advt. purposes | 37,404 | 78,914 | 93,948 | 60,270 | 22,815 | 27,988 | 37,905 | 14,846 |
| Other discharge lamps not exceeding 300 volts | 12,160 | 12,019 | .. | .. | 11,821 | 7,104 | .. | .. |

TABLE 70—IMPORTS OF DISCHARGE LAMPS FROM U.S.A.
(Qty in numbers and val. in \$)

| | 1948 | | 1949 | | 1950 | | 1951 | |
|-----------------------------|---------|--------|---------|---------|--------|--------|--------|--------|
| | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. |
| Fluorescent tubes and bulbs | 104,135 | 59,803 | 318,125 | 182,227 | 56,020 | 30,662 | 25,876 | 17,249 |
| Other discharge lamps | 28,684 | 2,309 | 97,730 | 6,588 | 34,377 | 4,215 | 4,720 | 1,213 |

to produce some of the warmer colours for display lighting. The advantages of this lamp are long life, instantaneous starting, and flexibility for decorative purposes (Hewitt, 94).

Fluorescent tubes of the hot cathode type are now being manufactured by the *ELMI* factory in Calcutta, their annual rated capacity being 400,000 tubes. Their total production was 73,164 tubes during 1952 (Information from the *Indian Lamp Factories Association*, Calcutta).

Tables 69 and 70 give the imports of discharge lamps from U.K. and U.S.A. into India.

Neon signs—Neon signs are low-pressure discharge tubes containing neon at a pressure of less than 10 mm. of mercury and fitted with cold cathodes. The electrodes consist of hollow iron cylinders. The tubes are operated on high voltage owing to the large voltage drop at the cathode (which is of the order of 150 volts) and the current is obtained from a high leakage reactance transformer.

Neon is widely used in 'signs' employed for advertisement purposes as it gives light of brilliant orange red colour. Neon signs have high efficiency (10 lm/W). Neon signs are also made with mercury filling in which case argon is used as a carrier gas. More usually, a mixture of neon and argon in the ratio of 10:90 or 20:80 is used as the carrier, the resulting light being blue.

Tubes of clear glass containing neon give a red-orange glow. Helium gives a yellow light and argon, blue. A mixture of rare gas and mercury vapour gives a blue colour. By the use of glass tubes of various colours, the colour range can be extended.

In the preparation of neon signs, a design of the letters of the alphabet and the figures constituting the sign are laid on drawing paper and then

on asbestos paper. A glass tube is taken, heated and bent to the shape of the design, and spliced together to form a continuous tube open at both ends. A hole is made in the tube and a small tube attached for evacuation and subsequent filling with the required gas. Electrodes with glass jackets are fitted at the ends. The tube is exhausted and a high voltage current from a 'bombarding' transformer passed when the electrodes and the tube are heated and adsorbed gases are set free. The gases are removed by a vacuum pump. When the pressure falls to 5 microns or less, the tube is filled with the required rare gas at 6–20 mm. of mercury (4–6 mm. of mercury in tubes of large diameter) and sealed. A small amount of mercury is introduced if a mercury vapour-rare gas mixture is desired. The tube is 'aged' by connecting it to a transformer and supplying either the rated or a higher current for a short period. The sign is fixed on a metal box in which are housed the transformer and supporting brackets. The electrodes are insulated and connections made. Flashers with different timings may be used for animation, and time switches for switching the sign on and off may be installed to attract attention.

Neon signs are produced in the bigger cities of India from imported lead and soda glass tubes, electrodes, and rare gases.

Neon glow lamps—Neon glow lamps are made with cold cathodes and short tubes. There is no positive column and the source of light is the negative glow near the cathode. They are used as indicator lamps, advertisement lamps, night lights, etc. The 5-watt 'beehive' glow lamp contains a spiral electrode of diminishing radius and a flat plate iron electrode. The gas pressure is c. 11 mm. of mercury. A trace of argon is introduced with

neon for ease in striking. The luminous efficiency of neon glow lamps is 0.3 lm/W and the brightness 0.1 stilb (Clarke, 72).

Motors

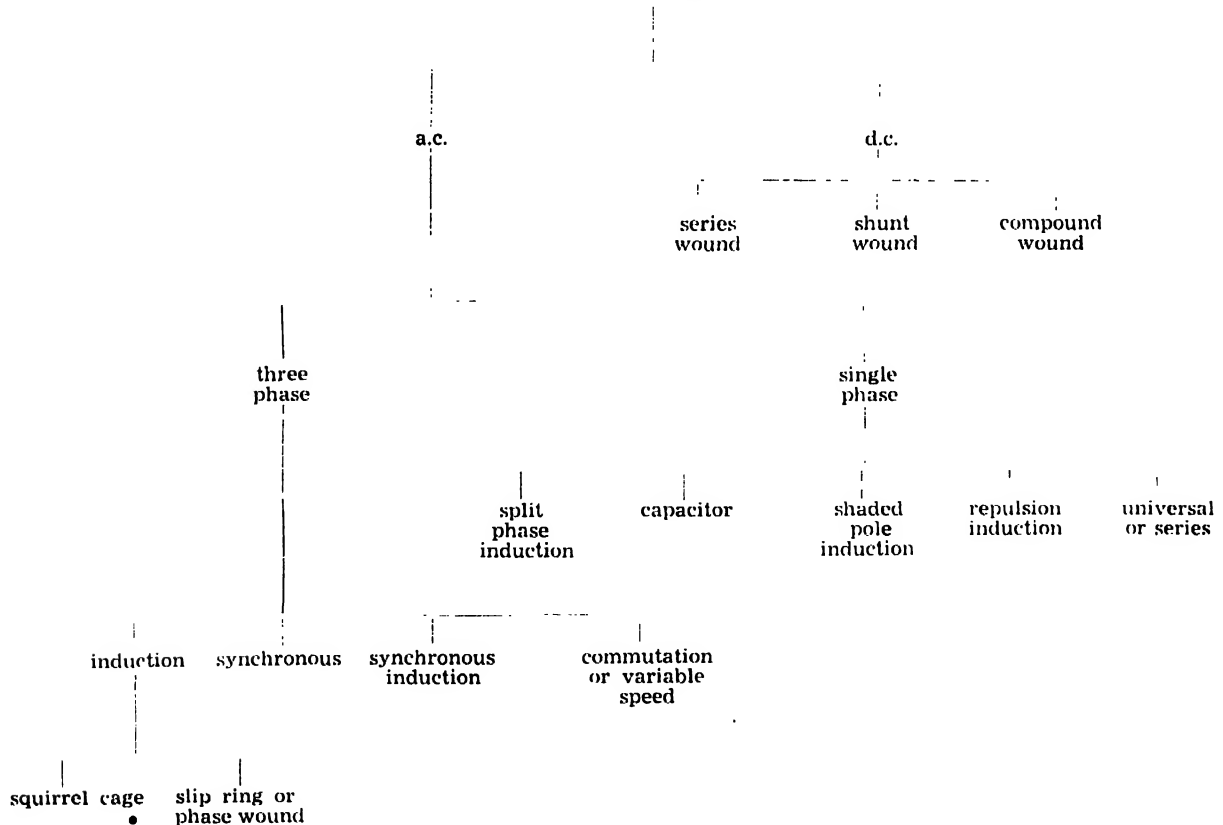
As a compact and convenient means of converting electrical energy to mechanical energy, the electric motor is a vital link between the supply of electricity and its utilization in agriculture and industry. It is used extensively as a source of motive power in flour and oil mills, textile mills, coal mining, transport, and engineering workshops; it is used also for lift irrigation in rural farming and in small-scale and cottage industries.

An electric motor consists of a static part (the stator or field) and a rotating part (the rotor or armature), both carrying windings. When the windings are energized by the passage of an electric current, magnetic fluxes are produced and the reaction of the stator and rotor fluxes produces a torque causing the rotor to rotate.

Electric motors may be classified broadly into d.c. motors and a.c. motors. They can be further sub-classified as follows :

In the d.c. motor the rotating part is the armature and the fixed part, the field coil. In the a.c. motor the fixed and rotating parts are respectively the stator and the rotor. The frame supports the stationary magnetic structure and, in small and medium motors, also the brackets carrying the bearings. The frame in the d.c. motor forms a part of the magnetic circuit and supports the carbon brushes which make contact with the commutator and carry the current to the armature coils. The stator magnetic structure consists of projecting poles (forming part of the frame in a.c. motors or bolted to the frame in d.c. motors) which carry the field; in a.c. motors, the stator also carries a laminated core with notches punched in the periphery. The field coils or stator windings consist of a large number of turns of insulated copper wire which carry the magnetizing current from the supply circuit. The torque or working current in a.c. motors is also taken from stator windings. In d.c. motors, however, it is taken into the armature through the brushes and the commutator. The field coils in d.c. motors are concentrated only at the poles, one coil on each

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pole, whereas in a.c. motors, the stator windings are split up into a number of smaller coils inserted in stator slots. Certain types of a.c. motors, such as shaded-pole induction motors and series motors, have concentrated field coils on salient poles as in d.c. motors.

The rotating part consists of the shaft, the magnetic structure, the armature or rotor windings, and the commutator (in d.c. motors and a.c. commutator motors) or slip-rings (in phase-wound induction and synchronous motors). The shaft rotates in bearings and transmits the mechanical torque to the machine by means of a pulley, a gear, or a coupling. The rotating part consists of a built-up core of thin laminated steel sheets with notches on the outer periphery for carrying armature or rotor coils. In synchronous motors, the rotor magnetic circuit consists of an annular steel rim on which are mounted salient, radially projecting poles of solid or laminated steel; the rotor windings surround the salient poles. In the induction motor, the motor windings consisting of many turns of insulated copper wire, lie in the slots of the armature. In squirrel cage induction motors, the armature consists of copper bars inserted in slots and joined at both ends by copper rings. Phase-wound induction motors and synchronous motors are provided with slip rings.

D.C. Motors

In series wound d.c. motors, armature and field coils are connected in series. The latter are made up of a relatively small number of turns of large cross section. The torque is proportional to the square of the current up to the point of magnetic saturation. Series wound d.c. motors are employed for electric traction, e.g. railways and tram cars, cranes, and auxiliary drives in rolling mills.

The shunt wound motor is a constant speed machine. The field coil consists of a relatively large number of turns of small cross section connected directly across the line voltage. Field and armature windings are in parallel across the supply mains. Shunt wound motors are used for machine tool drives, conveyors, cotton spinning machinery, air compressors, and pumps.

Compound wound d.c. motors are suitable for driving individual machines, such as winches and presses, in conjunction with fly wheels. Field poles are provided with a shunt as well as a low resistance series coil. A particular type of the compound wound d.c. motor is the compensated motor which contains, in addition, a compensating winding in series with the armature winding for compensating the magnetic effect of the working current on the field. Sparking is reduced and a flat torque-speed curve, with almost no change in speed from no load to maximum over-load, is ensured.

A.C. Motors

Induction motors—The stator of an a.c. three phase induction motor consists of a laminated core housed in a frame with a large number of conductors distributed in slots in the inner periphery. The rotor consists of a drum-shaped laminated core with slots in the outer periphery for carrying the windings. The stator winding is connected to a 3-phase power supply; the rotor has no physical connection to the power circuit. The power in the stator produces a uniformly rotating magnetic field caused by the pulsation of magnetic fields set up by the various phases. It induces e.m.f.'s in the rotor and the induced current produces a magnetic field in the opposite direction. The interaction of the two fields develops the torque. There would be no induction and no current in the rotor if the latter revolves at the speed of the stator field and the motor cannot operate at synchronous speeds even when it is idling. The percentage difference between the speeds, known as the slip, varies between 2 and 5% of the synchronous speed at full load.

At no load the speed of the motor is nearly that of the synchronous speed and the induced e.m.f. and current are small. When a load is applied the rotor slows down and the slip increases. The induced e.m.f.'s will increase in magnitude and frequency; a torque is produced to balance the torque applied to the rotor. The induction motor is thus a constant speed motor.

Induction motors are of two types—the squirrel cage and the slip ring. The former is the more common. It is extensively used on account of its robust construction. The rotor windings consist of solid copper bars in slots connected at each end to a short-circuiting ring. The end rings carry the summations of conductor currents. The greater the number of bars per pole, the more nearly is the resulting current sinusoidal.

Due to the exceptionally low resistance of the rotor bars, even a small induced voltage generates a large current. On account of the large phase angle at the start, the torque will be relatively small. The squirrel cage motor is therefore not suitable for starting under heavy loads.

Four types of squirrel cage motors are in use : (1) normal starting torque and current with cages of low resistance and reactance, low full load slip, good efficiency and power factor, and high pull-out torque; (2) normal starting torque and low starting current, large rotor reactance, same slip and efficiency as (1) but lower power factor and pull-out torque; (3) high starting torque and low starting current; efficiency, power factor, and pull-out torque less than in (1); (4) full load slip using a comparatively high resistance cage, with large starting torque, low starting current and low efficiency (Say, 291).

The slip ring motor varies from the squirrel cage motor in that the rotor is wound with insulated copper wires and housed in slots on the rotor. The rotor has, generally, a 3-phase winding, connected in star or mesh and terminated on 3 slip rings, which are short-circuited when the motor is running. A variable external resistance can be introduced in series with each phase to increase the resistance of the rotor windings and so produce a high torque. Once the motor has started against load, the external resistance can be gradually reduced until it is finally cut out at full speed.

The differences between the two types of induction motors are: (1) in a squirrel cage motor, the cage is permanently short-circuited and its electrical characteristics are fixed; in the slip ring motor, the winding permits variation of the electrical characteristics by the inclusion of external circuits via the slip rings and (2) in a squirrel cage motor, the cage is adaptable to any number of poles, whereas the slip ring winding has to be made for one (or possibly two) pole pair.

Synchronous motors—The stator of a synchronous motor is of the laminated type with poly-phase winding. The rotor field is produced by electro-magnets mounted radially on the shaft and excited by direct current supplied through slip rings. The mutual attraction of the rotating field of the stator and the field of the magnetized salient pole revolving rotor, causes the two sets of fields to lock together and to rotate synchronously. For starting, the rotor is driven within 5% of the synchronous speed either by an auxiliary motor or by providing a squirrel cage winding in the pole pieces. Synchronous motors are used for driving paper pulp beaters, centrifugal blowers, compressors, crushers, pulp grinders, steel rod mills, rolling mills, and rubber mills.

Single phase motors—The magnetic field in a single phase motor only pulsates and, for this reason, it is necessary to employ an auxiliary means to run the motor up to speed before the stator exerts a torque. Suitable electrical devices are provided to impart a torque at standstill. Usually, two windings, a running winding and an auxiliary winding, displaced from each other by 90 electrical degrees, are provided and for starting purposes the machine is converted into a 2-phase motor. The running winding is connected directly to the single phase supply; the starting winding is also connected to the supply but in such a way that the current flowing in it is out of phase with the current in the running winding; a rotating field is thereby produced. Once the motor is running the current in the auxiliary winding is no longer required and it is cut off by a centrifugal switch.

Single phase motors are of different types

depending on the starting device employed. The split phase induction motor has a running and an auxiliary winding, spaced 90 electrical degrees apart, on the stator. The two windings are designed with different inductances and/or resistances in order to produce a phase difference between the fluxes and connected in parallel, each winding forming a complete circuit in itself. The auxiliary winding has a starting switch in series and can be cut off from the supply when the rotor, which is of the squirrel cage type, has run up to speed. At the time of starting, the two windings are connected in parallel and when the speed reaches 75-80% of the synchronous speed, the switch opens the circuit.

The capacitor start motor is a split phase motor in which a dry type electrolytic capacitor is used in series with the auxiliary winding to produce the phase split. The construction is similar to that of the split phase motor, the squirrel cage rotor being identical. The capacitor in the starting winding is fixed directly to the outside of the motor. The centrifugal switch, which is inserted in the auxiliary winding, opens at 75-80% of the synchronous speed.

Capacitor run motors are of similar construction and have starting characteristics similar to those of capacitor start motors. They are so arranged as to leave a capacitance continuously in circuit and so improve the power factor.

Universal motor—The stator of a universal motor is of salient pole construction as in d.c. motors. The stator windings are concentrated in two coils, one round each pole. A variation of this type is the compensated universal motor with a compensating winding in series with the main winding and the armature. The compensated type has better universal characteristics (i.e. nearly the same speed on both a.c. and d.c.) than the non-compensated motor. The latter is less expensive than the compensated motor and is generally used for lower ratings and for higher speeds. The speed with either type drops off rapidly with increase in load.

Repulsion start induction motor—The rotor is wound with insulated wires in the same manner as the stator. The armature windings are connected to a commutator and the two brushes are short-circuited on themselves. A centrifugally operated ring short-circuits the commutator segments making the armature, in effect, a squirrel cage rotor. The repulsion motor is extensively used for applications requiring a high starting torque and a comparatively low starting current.

Shaded pole induction motors have no commutators, switches, or collecting rings and employ salient poles. The running winding is concentrated into a few coils, usually one for

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each pole, and the auxiliary winding, which is not connected to the power supply, consists of short-circuited copper loops or shading coils. One coil is placed around a portion of each pole, displaced from the main winding by almost 90 electrical degrees. It causes the flux in the shaded portion to lag behind the flux in the rest of the pole. The rotor is of the squirrel cage type. Table 71 summarizes the uses of single phase motors.

THE INDIAN INDUSTRY

The manufacture of electric motors in India was started before World War II by *P.S.G. & Sons' Charity Industrial Institute*, Coimbatore. The annual output was 150 motors, 1-10 h.p., a.c. 3-phase, squirrel cage rotor type. Messrs. *Crompton Parkinson (Works) Ltd.*, Bombay commenced manufacture of motors a little later and produced during 1939 approximately 200 units. Messrs. *Kirloskar Brothers Ltd.* produced, as an experimental measure, about 12 motors during the same year.

The war gave a stimulus to the development of the industry and while the firms established before the war expanded their production capacities, two other firms—*Associated Electrical Industries Manufacturing Co. Ltd.*, Calcutta and *British India Electric Construction Co. Ltd.*, Calcutta—were established during the war period. At the end of the war, the installed capacity for a.c. 3-phase squirrel cage motors, 1-30 h.p., had increased to 60,000 h.p. per year (about 12,000 motors).

Since the end of the war, the industry has

further expanded and ten more factories have come into existence. Also, *Crompton Parkinson (Works) Ltd.* and the *Associated Electrical Industries Mfg. Co. Ltd.* have expanded their production substantially. Production by *Kirloskar Bros. Ltd.*, Kirloskarwadi was abandoned by the end of 1947, and a new factory, *Kirloskar Electric Co. Ltd.*, Bangalore was set up with equipment and machinery belonging to the former factory. The Bangalore factory commenced production in 1948. There are now 12 organized factories producing electric motors with an aggregate annual capacity of over 200,000 h.p. These are: (1) *Crompton Parkinson (Works) Ltd.*, Bombay, (2) *National Electrical Industries Ltd.*, Bombay, (3) *Electric Construction & Equipment Co. Ltd.*, Calcutta, (4) *Bharat Bijlee Ltd.*, Bombay, (5) *Associated Electrical Industries Mfg. Co. Ltd.*, Calcutta, (6) *Kirloskar Electric Co. Ltd.*, Bangalore, (7) *P.S.G. & Sons' Charity Industrial Institute*, Coimbatore, (8) *Jyoti Ltd.*, Baroda, (9) *Motor Machinery Manufacturers Ltd.*, Calcutta, (10) *General Electric Co. (India) Ltd.*, Calcutta, (11) *Mysore Government Electric Factory*, Bangalore, and (12) *Hindustan General Electric Corporation*, Calcutta. Six other firms are producing fractional h.p. motors exclusively. They are: *India Electric Works Ltd.*, Behala (West Bengal), *Polar Electrical Engineering Co. Ltd.*, Calcutta, (West Bengal), *G.B. Works Ltd.*, Rishra (West Bengal), *Metropole Works*, Amritsar, *G.T.R. Company Ltd.*, Calcutta, and *Machineries and Industries (India) Ltd.*, Chinsurah (West Bengal).

TABLE 71—USES OF SINGLE PHASE MOTORS

| | Rating (h.p.) | Characteristics | Uses |
|---------------------------|---------------|---|---|
| Split phase induction | 1/20 to 1/3 | Constant speed up to 150% full load torque | Used where small amounts of power are needed and where appliances are required to be brought up to speed quickly, e.g. washing machines, oil burners, blowers, centrifugal pumps, wood working tools, bottle washers, churns, automatic musical instruments, buffing machines, grinders, and machine tools. |
| Capacitor start induction | 1/10 to 10 | Constant speed up to 400% full load torque | Refrigeration, stokers, oil burners, and other household appliances, where a higher torque is required than is available from split phase motors |
| Shaded pole | 1/75 to 1/20 | | Widely used for driving appliances, such as advertising devices, damper controllers, fans, humidifiers, radio controls, and hair driers |
| Repulsion | 1/8 to 5 | Up to 400% full load torque at starting; low starting current | Meat and coffee grinders, shoe machines, and other similar appliances |
| Universal | 1/150 to 1 | High starting torque; efficient at 4,000 to 10,000 r.p.m. | Drills, blowers, vacuum cleaners, and sewing machines |



Crompton Parkinson (Works) Ltd., Bombay

FIG. 47—MACHINING OF MOTOR CASTINGS

The total number of persons employed in the electric motor industry is estimated at 1,600.

Raw materials—The principal raw materials and components used in the manufacture of electric motors are pig iron, steel, silicon steel stampings, copper wires, insulating materials, and bearings. Of these, the first four are produced in the country. Silicon steel stampings are supplied by *Sankey Electrical Stamping Ltd.*, Bhandup (Bombay) from steel manufactured by *Tata Iron & Steel Co. Ltd.*

Cotton-covered wire with single or double layers of cotton and a part of the enamel wires are produced in India.

Electrolytic copper bars used for squirrel cage rotors are supplied by *National Insulated Cable Co. of India Ltd.*, Calcutta and *Indian Cable Co. Ltd.*, Jamshedpur. Aluminium is used by *Associated Electrical Industries Mfg. Co.*, Calcutta for die-cast squirrel cage rotor windings.

Hand-drawn electrolytic copper bars, used for making commutator segments for d.c. motors, are imported.

End rings for squirrel cage rotors are made either from copper or from copper alloyed with zinc. Slip rings for phase wound induction motors are made of gun metal.

In addition to using insulated wires for windings, it is necessary to insulate the coils from the slots. The insulating material used for this purpose also protects coils from mechanical injury due to

contact with core stampings and slot wedges. The materials employed for this purpose are vulcanized fibre, leatheroid, and presspahn paper. Many manufacturers use leatheroid in conjunction with flexible micanite sheets. Varnished cloth, such as empire cloth, in combination with leatheroid, is also used as slot insulation. White Egyptian cotton tape and empire tape are used for insulating coil ends or overhangs. All insulating materials, except mica and micanite and white cotton tape, are imported; small quantities of empire cloth are manufactured by *India Electric Works Ltd.*, Calcutta.

Insulating varnishes are employed for impregnating rotor and stator windings. This treatment gives extra insulation to coil conductors, prevents moisture absorption, and keeps out dust and dirt. Bitumen base varnishes and shellac base varnishes used for this purpose are now being replaced by synthetic resin based polymerizing varnishes.

Ball bearings are manufactured in India at Jaipur by the *National Bearing Co. Ltd.*

Table 72 gives the requirements of raw materials for the production of 35,000 a.c. 3-phase squirrel cage motors of 1-50 h.p. (c. 175,000 h.p. on the basis of 5 h.p. as the average output).

Manufacture—The stator consists of a machined cast iron frame with end covers, the core, and the coils. The frame is perforated for ventilation and supports two end shields which carry the bearings. Motors with totally enclosed frames are also manufactured in India.

Cores for both stator and rotor are made from dynamo grade silicon steel. Circular blanks are pressed out and a central hole with a notch is punched. The central portion is blanked out and

TABLE 72—REQUIREMENTS OF RAW MATERIALS FOR THE PRODUCTION OF MOTORS*

| | Qty (tons) |
|---------------------------------------|---------------|
| Copper ingots | 141 |
| D.C.C. copper wire & strips | 132 |
| Electrical steel sheets, dynamo grade | 1,830 |
| Ball bearings | 70,000 |
| Welding rods | 3.5 |
| Leatheroid | 3 |
| Iron castings | 1,251 |
| Steel bars, IRS specification M-4/34 | 220 |
| Empire cloth | 5 |
| Black adhesive tape, ft. | 140,000 |
| Nuts and bolts | 47 |
| Packing plants, c. ft. | 1,120 |
| Hoops | 70 |
| Wire nails | 17.5 |
| V.I.R. wire | 6 |
| Insulating varnish and thinners, gal. | 5,250 |

*I. & S. Bull., 1949, 2(3), 26



Crompton Park: (Works) Ltd., Bombay

FIG. 48—WINDING OF STATORS AND ROTORS

used for the rotor while the outer portion is utilized for the stator core.

Stator and rotor punchings are notched for the insertion of coils. Rotor punchings have slots on the outer periphery, whereas stator punchings are cut near the inner periphery. Ventilating holes are punched in rotor laminations to provide air circulation.

Rotor punchings are arranged one above the other with the central notches in one line and fixed with a key rod. The assembly is fixed to the hub of the shaft. In large sized motors in which the diameter of the hub is much greater than the shaft diameter, the hub is made as a separate unit and fixed to the shaft.

Stator punchings are similarly assembled in a jig one above the other in such a way that the notches form slots. The core is inserted into the frame and its inside is ground to form an air gap between stator and rotor cores.

Stators for induction motors are generally wound with fed-in coils, the sides of which are untaped. This makes possible the feeding of

wires into partially open slots. The "diamond coil" is used for large sized machines. The coil is wound, shaped, and ends taped with half lapped cotton tape, before the coil is fed into the slots. The leads are brought out near the point of the diamond so that a number of coils lying in adjacent slots can be series-connected to form a phase group. In smaller motors, "basket coils" are used; these are wound to the approximate shape but are not taped except at the corners until they are inserted in the slots. The ends of the coils are then taped.

Small sized single phase a.c. stator coils are of the skein type, rectangular or oval.

Rotor windings for use in slip ring rotors (wound rotors) are usually of the pull-through type as the slots are closed. The ends of windings for each phase are connected together in the same way as in stator coils.

Stator coils and wound rotor coils are form-wound and the ends taped. Stator coils for fractional h.p. motors are also hand-wound from a spool. The leads are brought out near the point



Crompton Parkinson (Works) Ltd., Bombay

FIG. 49—PACKING OF FINISHED MOTORS

of the diamond and covered with cotton sleeveings which extend back (to c. 1 in.) into the coil.

Stator and rotor coils for bigger motors, after they have been formed, are impregnated with insulating varnish before insertion into the slots. Air-drying or baking varnishes are used for this purpose. The varnish is usually applied by immersion, though brushing and spraying methods are also used. Prior to dipping, the coils are dried at 90–100° to drive off moisture. Impregnated coils are then baked.

Formed and impregnated coils are next inserted in the stator. Prior to this operation, slots are insulated to protect the coils from grounding. They are lined with leatheroid (thickness, 0.007–0.01 in.) or fish paper and one or two layers of mica foil, empire cloth, or varnished cambric. In partially closed openings, wires are inserted into

slots, a few at a time, until the coil is in place. Projecting slot insulations are folded over the coils and a fibre wedge slipped into the slot to prevent the coil coming out. The ends of the coils are taped and shaped to fit compactly into the smallest possible space. The ends are joined and free ends of the different phases are brought out to the terminal box. The various phases are tested for resistance and current per phase and the entire stator assembly and, in the case of slip ring motors, the wound rotor assembly, are dried, dipped in varnish, drained, and baked.

In the case of squirrel cage rotors, heavy electrolytic copper bars are driven into the closed rotor slots from the end of the core round the periphery and the ends silver-soldered or brazed to copper or brass end rings. Insulation is not usually applied between the rotor conductors and the slots in

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squirrel cage rotors on account of the extreme low voltage of the current in the bars. The outside of the core is machined to ensure accurate centering in the stator bore. End rings are cast or cut from cast copper cylinders.

Bearings and bearing caps are fitted. The assembled motor is tested, painted, and packed.

The production of d.c. motors is carried out in the same way as a.c. induction motors. The field magnetic structure is made by casting a single block with projecting pole pieces or, in some cases, by bolting pole pieces of iron laminations to the shell. The centre of the magnetic structure is bored to give a uniform air gap.

Field coils are made by winding a few hundred to several thousand turns according to the size and voltage of the motor. Prepared coils are varnish-impregnated, baked, and slipped over the pole pieces.

The armature is made of slotted black sheet or silicon steel laminations and clamped by bolts. The armature core and the commutator are pressed into the shaft. Armature coils are either preformed or wound on armature slots by hand. The complete armature is varnish-impregnated and baked. It is then inserted into the field bore and end covers, complete with bearings, are fixed on to the frame. The completed motor then goes for testing.

Production—The pre-war capacity of manufactured electric motors was 9,000 h.p. The capacity increased to 60,000 h.p. or 12,000 motors (a.c. 3-phase squirrel cage, 1-30 h.p.) by 1945. The capacity was 150,000 h.p. in 1948. A.C. 3-phase squirrel cage motors up to 75 h.p. are now produced in India on an organized scale.

Slip ring induction motors are being produced by *Kirloskar Electric Co. Ltd.*, Bangalore since 1950. The sizes produced are: 10-30 h.p., 1,500-720 r.p.m.; 10-30 h.p., 1,500-1,000 r.p.m.; and 50 h.p., 1,500 r.p.m. Enclosed electric motors for ring spinning frames are also produced by this firm.

Other types of motors produced in India are: vertical spindle, squirrel cage motors of both flange mounting and skirt mounting (2 h.p., 1,450 r.p.m. to 20 h.p., 1,450 r.p.m.); 2, 3, and 4 speed squirrel cage motors up to 20 h.p., screen protected or drip proof; short time rated high torque motors for lifts, cranes, etc., up to 12.5 B.h.p.; totally enclosed, fan-cooled special motors with smooth acceleration for driving ring frames, doubling frames, and other textile machines (single speed, up to 30 B.h.p. and 2, 3 or 4 speed for lower capacities); and totally enclosed, fan-cooled, smooth acceleration motors up to 12 h.p.

Messrs. Kirloskar Electrical Co. Ltd., Bangalore have recently extended the range of production to 100 h.p. motors in technical collaboration with *Messrs. Brush Engineering Co.*, U.K. They have also plans to take up the manufacture of motors

above 100 h.p. and expect to increase the capacity to 75,000 h.p. *Messrs. Associated Electrical Industries Manufacturing Co., Ltd.* and *Messrs. G.E.C. (India) Ltd.* have also plans to extend the range

TABLE 73—PRODUCTION OF ELECTRIC MOTORS

| | No. | h.p. |
|------|--------|---------|
| 1946 | 9,424 | 45,880 |
| 1947 | 8,913 | 38,000 |
| 1948 | 13,964 | 60,000 |
| 1949 | 13,100 | 68,050 |
| 1950 | 14,800 | 81,795 |
| 1951 | n.a. | 142,799 |
| 1952 | n.a. | 157,477 |

n.a. not available

TABLE 74—PRODUCTION OF ELECTRIC MOTORS
ACCORDING TO H.P.*

| h.p. | No. | Total h.p. |
|---------|--------|------------|
| Below 1 | 1,532 | 825 |
| 1 | 1,849 | 1,849 |
| 1.5 | 645 | 967.5 |
| 2 | 1,728 | 3,456 |
| 2.5 | 27 | 67.5 |
| 3 | 2,523 | 7,569 |
| 3.5 | 3 | 10.5 |
| 4 | 276 | 1,104 |
| 4.5 | 1 | 4.5 |
| 5 | 2,832 | 14,160 |
| 6 | 171 | 1,026 |
| 7.5 | 1,435 | 10,762.5 |
| 8 | 24 | 192 |
| 9 | 2 | 18 |
| 10 | 727 | 7,270 |
| 12 | 10 | 120 |
| 12.5 | 149 | 1,862.5 |
| 15 | 271 | 4,065 |
| 20 | 32 | 640 |
| 25 | 74 | 1,850 |
| 30 | 1 | 30 |
| Total | 14,312 | 57,849 |

* Indian Tariff Bd, *Rep. Continuance of Protection to the Electric Motors Industry*, 1949, 27

TABLE 75—IMPORTS OF ELECTRIC MOTORS

| | Val. (Rs.) |
|-----------------------|---------------|
| 1934/35-1938/39 (av.) | 44,53,355 |
| 1939/40-1943/44 (av.) | 42,88,035 |
| 1944-45 | 67,10,202 |
| 1945-46 | 69,72,883 |
| 1946-47 | 95,77,928 |
| 1947-48 | 1,76,58,520 |
| 1948-49 | 3,14,43,626 |
| 1949-50 | 2,52,31,781 |
| 1950-51 | 1,41,03,623 |
| 1951-52 | 1,11,74,118 |
| 1952-53 | 1,22,90,168 |

TABLE 76—IMPORTS OF ELECTRIC MOTORS FROM U.K.

| | 1946 | 1947 | Qty | | 1950 | 1946 | 1947 | Val. (£) | | 1950 |
|---|-------|-------|-------|-------|---------------|---------|---------|------------|-----------|---------|
| | | | 1948 | 1949 | | | | 1948 | 1949 | |
| Complete motors for railways and tramways, tons | 27 | | | | | 9,952 | 773 | 550 | | |
| Complete motors | | | | | | | | | | |
| not exceeding 1/3 h.p., cwt. | 729 | 1,851 | 1,461 | 2,212 | 390 (1,815) | 12,689 | 47,317 | 40,710 | 71,715 | 14,466 |
| exceeding 1/3 h.p., but under 1 h.p., cwt. | 1,152 | 2,255 | 2,894 | 2,188 | 368 (505) | 17,637 | 48,984 | 67,132 | 48,093 | 7,118 |
| from 1 to 250 h.p., tons | 2,497 | 2,559 | 3,559 | 3,739 | 1,716 (5,304) | 494,583 | 666,214 | 1,042,417 | 1,081,951 | 543,551 |
| exceeding 250 h.p., tons | 84 | 166 | 297 | 295 | 174 (33) | 25,665 | 36,808 | 74,597 | 90,850 | 51,751 |
| Parts of motors, tons | 130 | 161 | 239 | 376 | 279 | 37,750 | 60,006 | 72,050 | 118,941 | 127,326 |

Figures within brackets indicate number of motors

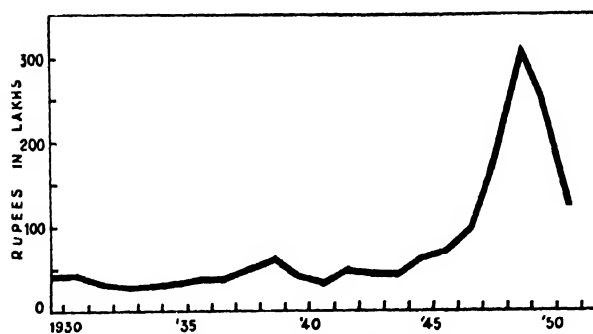


FIG. 50—IMPORTS OF MOTORS

of their production to 100 h.p. and 50 h.p. electric motors respectively. A scheme for the manufacture of motors is under the consideration of the Government of India.

Table 73 gives the production of a.c. motors in India. Table 74 gives the production of electric motors of different h.p. during 1948.

The present annual requirements of electric motors have been estimated at 300,000 h.p., a little over 100,000 of which are made up of motors up to 30 h.p. The demand for 3-phase squirrel cage motors, 1-30 h.p., is about 200,000 h.p. per annum or 35,000 to 40,000 motors (Indian Tariff Bd, Rep. Continuation of Protection to Electric Motors Industry, 1949, 5; Information from D.G.I. & S.).

The Planning Commission has estimated that the total requirements of a.c. 3-phase squirrel cage and slip ring induction motors, up to 50 h.p., would increase to about 320,000 h.p. by 1956.

TABLE 77—FAIR SELLING PRICE* (Price in Rs. as. ps.)

| h.p. | 1947 | | 1950 | | | | | |
|------|------|------|------|-------------------|-----|------------------|-----|--|
| | | | 1 | | 3 | | 7.5 | |
| | 157 | 7 10 | 285 | 5 0 | 290 | 9 8 | | |
| | | | 249 | 9 4 ⁺ | 243 | 3 3 ⁺ | | |
| | 187 | 9 10 | 317 | 10 1 | | | | |
| | | | 281 | 9 5 ⁺ | | | | |
| 7.5 | 239 | 13 9 | 455 | 15 4 | | | | |
| | | | 411 | 15 7 ⁺ | | | | |

* Indian Tariff Bd, Rep. Continuation of Protection to the Electric Motors Industry, 1949, 15

⁺ Estimates based on production to full capacity

TABLE 78—FAIR SELLING PRICE AND LANDED COST*

| | Price (Rs. as. ps.) | | | | | |
|------------------------------|---------------------|------|--|--------|-----|--|
| | 3 h.p. | | | 5 h.p. | | |
| C. i. f. | 280 | 0 0 | | 256 | 0 0 | |
| Landed cost (including duty) | 231 | 13 6 | | 285 | 5 8 | |
| Fair selling price | 243 | 3 3 | | 281 | 9 5 | |

* Indian Tariff Bd, Rep. Continuation of Protection to the Electric Motors Industry, 1949, 16

Imports.—Table 75 gives imports of electric motors into India.

Except a.c. 3-phase squirrel cage and slip ring motors up to 30 h.p., all other types are allowed to be imported at present.

Table 76 gives imports of electric motors from U.K.

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The shares of different countries in the imports of electric motors during the quinquennium ending 1938-39 were : U.K., 54.7; U.S.A., 9.4; Sweden, 4.4; and Germany, 2.2%. U.K. was the principal supplier in the quinquennium ending 1943-44, her share being 74%; other exporters were Sweden, Germany, Switzerland, and U.S.A. Imports of electric motors are subject to a protective duty of 10% *ad valorem*.

Price—Table 77 gives the fair selling price of 3 h.p., 5 h.p., and 7.5 h.p. motors, as estimated by the Tariff Board in 1947 and 1950. Table 78 provides a comparison of the fair selling prices of indigenous motors as estimated by the Tariff Board in 1950, c.i.f. prices, and landed costs of imported motors.

Radio Receivers and Components

The manufacture of equipment employed in radio communication—wireless telegraphy, wireless telephony, broadcasting, television, etc.—has attained great importance in all advanced countries. Progress in radio communication has been rapid because of its numerous applications and amateur and professional radio enthusiasts have contributed materially to the growth of the radio equipment manufacturing industry.

Radio communication is carried on by means of electrical energy which travels in the form of high frequency electromagnetic waves from the transmitter to a receiver with the velocity of light. The transmitter produces radio frequency energy and incorporates devices for utilizing this energy to produce radio waves of a particular frequency, known as the 'carrier wave', and for modifying the wave in accordance with the information to be transmitted. In broadcast transmission, the carrier wave is modified by speech or music currents from the microphone.

The modulated radio-frequency waves from the transmitter are radiated into space by an antenna consisting of a system of over-head wires. Directional characteristics are imparted to the antenna, and this is important because only those waves radiated in the direction of the receiver point reach that point and the waves radiated in all other directions are wasted so far as that particular receiving point is concerned.

The equipment at the receiving end consists of an aerial or antenna system to abstract the energy from radio waves passing the receiving point and a receiver with means to separate the desired signal from other signals and to reproduce the original information. The separation of the desired signal from other signals is effected by making the antenna and other circuits resonant to the frequency of the wave to be received. The transmitted information is recovered from the radio-frequency carrier wave by demodulation.

Since the system in practical use transmits information by varying the amplitude of the radiated carrier wave, demodulation or detection must produce currents which vary according to the modulation and this is achieved by the rectification of the radio-frequency currents. A series of tuned circuits are incorporated in the receiver to ensure selectivity. In addition, arrangements are provided for amplifying radio-frequency and rectified currents.

Broadcasting has given a great impetus to receiver design and a new industry has come into existence. Receivers used in broadcast reception can be grouped under two classes—straight sets and superheterodyne sets. In straight sets, the incoming signal is selected, amplified at its original frequency, the amplified wave rectified, and the resulting audio-frequency wave is again amplified. The bulk of receivers used at present are of the superheterodyne type. The superheterodyne receiver consists of three sections—radio-frequency (R.F.), intermediate-frequency (I.F.), and audio-frequency (A.F.) sections. The R.F. section is tuned to the signal frequency and delivers a R.F. voltage to a frequency converter which alters the frequency of the incoming wave to a lower, fixed, and predetermined intermediate frequency containing the original modulation by the use of the heterodyne principle, i.e. beating with another wave produced locally in the set. The I.F. section is tuned to the intermediate frequency and delivers an I.F. voltage to a detector which separates the signal modulations from the I.F. wave. The resulting A.F. wave is amplified by the A.F. system and delivered to a loud speaker for reproduction. Generally, the R.F. and A.F. sections contain one or more stages of amplification and the A.F. system, at least one stage of voltage amplification followed by power amplification. A large measure of magnification and selectivity is readily achieved by the heterodyne method. However, the quality of reception is usually superior with a straight set.

In addition to the essential elements, radio receivers are provided with one or more special devices, such as automatic volume control (A.V.C.), manual volume control, tuning indicators, tone control, quieting arrangement, and automatic frequency control, depending on the quality and price of the receiver.

In the method of transmission now commonly used in broadcasting, the amplitude of the carrier wave is modulated by speech or music currents. The defects in amplitude modulation arise out of the limited band width of the I.F. stage, which restricts the quality and the fidelity of reception. Also, fading of signals and interference due to atmospherics are particularly noticeable.

Transmission by frequency modulation (F.M.),

which is now coming into vogue in broadcasting at ultra-high frequencies (28 megacycles or higher), is comparatively less affected by extraneous disturbances and the quality of reception is usually better. For detection, the frequency-modulated wave is converted into an amplitude-modulated wave by an 'off-tune' resonant circuit so that the received frequency falls slightly to one side of the resonant point; as the frequency of the modulated wave varies, the response to the tuned circuit becomes alternately large and small, thus producing amplitude modulation. An experimental frequency modulation transmitter has been set up in Delhi by the All India Radio.

Broadcast receivers are mounted on chassis of plated metal sheet bent in the form of an inverted tray. The chassis is punched to receive sockets, coils, transformers, and other components. Bulky items, such as tubes, transformers, coil assemblies, gang tuning condensers, and electrolytic condensers, are mounted on the top side of the chassis, while small parts, such as by-pass condensers, are placed below. The chassis is slipped into a cabinet and connected to a loud speaker by a flexible cord terminating in a plug.

RAW MATERIALS

The principal raw materials required for the manufacture of radio parts and components other than valves are the following:

Metals—Silver and gold-silver for vibrator contacts; copper, iron (soft iron), steel, magnet steel (for permanent magnet), and stalloy; manganese, chromium, cobalt, nickel, uranium, tin, lead, aluminium, zinc, and tin; copper and aluminium foils (thickness, 1 to 4 mils; purity, 99.95%); aluminium sheet (thickness, 3 mils.); aluminium framework; copper wires of various gauges and Litz wires.

Alloys—Eureka, nichrome, manganin, phosphor bronze, brass, cold rolled phosphor bronze, brass sheets, and lead-tin alloy.

Insulating materials—Silk, cotton, rubber, insulating enamels, impregnating compounds, wax, porcelain, bakelite or shellac moulding powder, mica, pitch, resin, insulating sleeveings, leatheroid paper, empire cloth, and ebonite; H.F. porcelain (steatite, isolantite), laminated insulating boards (Paxolin, Dilecto); and sealing compounds.

Adhesives, varnishes, and chemicals—Cameron glue, casein glue, dextrin paste and solution, casein paste, Durifix, Golden lacquer, steatite slab, boric acid and salts, cadmium salts, Aquadag.

Miscellaneous materials—Thin kraft paper (thickness, 0.5 to 2 mils), tissue paper, paper and paper pulp for loud speaker cones, pressboard, presspahn paper, rubber latex, graphite, sand, talc, asbestos pulp, wood for cabinet, special cloth for speaker baffles.

COMPONENTS

The components of radio receivers are listed below:

Valves

Capacitors or condensers—Variable condensers (air dielectric), tubular paper capacitors, mica capacitors, ceramic capacitors, compression type trimmers, electrolytic capacitors

Resistances—Solid composition (carbon type), wire wound (vitreous enamelled), variable resistances (carbon track type)

Transformers—Mains transformers, output transformers, coupling transformers and L.F. filter chokes, I.F. transformers

Loud speakers—Permanent, energised

Metal parts—Chassis, dial support panel, tuning drum and pointer, idler pulleys, tuning shaft, brackets, spacers, springs, pilot lamp sockets, screws, washers, bolts, nuts, and rivets

Other Items—Knobs, insulated terminal strips, grommets, drive cord, grille cloth, plugs, dial scale, scotch tape and adhesives, radio wires (insulated), mains cord, washers (felt), ballast tubes, R.F. coils, rotary wafer switches, wooden and plastic cabinets, and cabinet backs

VALVES

Radio communication owes much to the development of the thermionic valve or vacuum tube, which is the most essential component of all radio apparatus. A large variety of valves are available in sizes and types ranging from a small radio receiving tube consuming a fraction of a watt to a radio transmitting valve several feet long and delivering more than 100 KW. of high frequency power. Thermionic valves are used for power amplification, voltage amplification, frequency conversion, detection, rectification, current regulation, voltage regulation, and as mixer tubes and oscillators.

The thermionic valve consists of a heated cathode which emits electrons and one or more electrodes which control and collect the electrons, mounted on a suitable supporting structure in an evacuated glass or steel envelope.

Air and other gases are removed from the envelope in vacuum tubes to eliminate the retarding effect of the gaseous atmosphere on the emission of electrons and also to obviate effects due to the ionization of gas by impact with electrons.

The simplest vacuum tube, the diode, consists of two electrodes—a cathode or filament and an anode or plate. When the outside terminal of the plate is made positive with respect to the cathode by connecting to a current supply in the plate-to-cathode circuit, the electrons which are emitted by the heated cathode flow across the space to the plate and then back to the cathode through the connecting conductor. As the plate voltage is increased, more electrons are attracted to the

plate until a stage is reached when all the electrons emitted from the cathode are drawn to the plate. Further increase in the plate voltage is not accompanied by any increase in plate current. When, however, the plate is made negative with respect to the filament, it repels the electrons so that there is no noticeable flow of current from the filament to the plate. With an a.c. voltage, the plate current flows only during the time the plate is positive. The diode has thus a rectifying action. Diodes are used in a.c. receivers to supply d.c. voltage to other tubes. They are also used for detection and automatic volume control.

The plate current flowing in a diode is limited by two factors—the maximum emission of the cathode (saturation current) and the accumulation of electrons in the space around the cathode (space charge). If the emission is increased by raising the cathode temperature, both the number of emitting electrons and the space charge increase until equilibrium is established. The introduction of a third element—grid—between the filament and the plate, as in the triode, helps in controlling the flow of the plate current. The grid is made in the form of a mesh so that as much space as possible is available for the passage of electrons from the filament to the plate. The grid surrounds the filament and is maintained at a potential more negative than the cathode so that electrons may not be attracted to the grid. The plate current depends on the combined effect of the grid and plate voltages. Small variations in the potential applied to the grid produce large variations in the plate current. The triode can, therefore, be used as an amplifier.

Additional electrodes are introduced to overcome the effects of electrostatic capacity between the plate and the grid, secondary electron emission from the plate, and so on. Multigrid tubes—tetrode, pentode, hexode, heptode, and octode—each designed to possess specific characteristics and used for specific applications have been developed. Multiple-unit tubes, containing in a single envelope two or more groups of electrodes associated with separate electron streams and performing simultaneously the functions of more than one tube—e.g. twin diodes, twin triodes, duodiode-triodes, duodiode-pentodes, and triode-pentodes—have been developed for use in radio circuits. Combinations of multi-electrode and multi-unit tubes, such as the pentagrid converter, have also been developed. Gas-filled tubes, e.g. thyratron and ignitron, are of more recent origin and are widely used for control purposes. These developments have given the vacuum tube, which was initially designed as a communication device, an important place also among the tools of the power engineer.

The thermionic cathode is the source of electrons in all vacuum tubes. It is in the

form of an incandescent filament—directly heated cathode—or a coated surface heated by a tungsten filament—indirectly heated cathode or heater type cathode. The directly heated cathode consists of a filament of tungsten or of thoriated tungsten. For lower voltages, a nickel surface coated with alkaline earth oxides is used. Such a surface may be directly or indirectly heated. Pure tungsten is seldom used as filament material except in high power transmission tubes. Thoriated tungsten, containing a small percentage of thorium oxide emits electrons more copiously. Oxide-coated cathodes are efficient emitters. The coating consists of barium and strontium oxides. Nickel is used as the base. Konel (Ni, 73; Co, 17.5; Fe, 6.5; Ti, 2.5; and Mn, 0.23%) has also been used. The coating is applied by drawing the wire or ribbon through a series of baths containing a suspension of barium and strontium carbonates and then through ovens till a coating of oxides of the required thickness is built up. The indirectly heated oxide-coated cathode consists of an oxide-coated nickel cylinder heated by a separate wire carrying the heater current. The use of oxide-coated cathodes is limited to applications in which both the power requirements and the operating voltages are low.

Grids are made of thin wires of molybdenum, nichrome or iron-nickel or manganese-nickel alloys. In some tubes, a part of the grid is made of graphite. Grids are designed specially to conduct away the heat received as radiation from the cathode and they are given a black rough surface to facilitate cooling.

Anodes of small high vacuum tubes are made of nickel or iron, pressed out of sheets and crimped or flanged to impart rigidity. The anodes receive the electron bombardment and must, therefore, be designed to dissipate heat. In the larger sizes of tubes, the anodes are blackened to increase heat radiation. The anodes of power tubes are often made of graphite. Copper is also frequently used, when it can be water-cooled to keep the operating temperature low.

Tube envelopes are made of soda-lime glass or steel. Mica is used for insulation and for the spacing of electrodes. Where the insulation is required to stand temperatures of 500° or more, alumina, magnesia, or steatite, pressed to shape from powdered materials and sintered at 1,500°–1,800° is employed.

The technique employed in the manufacture of vacuum tubes is somewhat similar to that employed in the production of incandescent electric lamps. The electrodes are supported by lead-in wires held in a glass 'press' at the base of the tube. The supporting wires consist of an upper portion of nickel, molybdenum or nickel-molybdenum alloy, a middle portion of Dumet for the glass-metal seal, and a lower portion of

copper for outside connection. The exhaust tube and the lead-in wires are grouped in proper relation to one another inside a stem-tube heated by a gas flame which causes the glass to fuse with the Dumet part of the lead-in wire embedded in it; the softened glass is pressed and a side opening for evacuation is formed while the glass is still soft. The electrodes are separately fabricated and spot welded to the supporting wires. They are held in proper space relation to one another, within a few hundredths of an inch, by means of punched mica discs to ensure satisfactory performance. The complete stem assembly is inserted into the glass bulb, the bottom of the press is sealed to the envelope, the tube evacuated, and based.

In metal tubes, the electrodes are assembled in the same manner as in glass tubes, but supported from a metal 'header'. The lead-in wires are taken through glass beads and sealed to 'kovar' eyelets welded to the header.

Protection against dust, corrosion, and oxidation, is important in tube production. The raw materials should be pure and of uniform composition. Evacuation of tubes is carried out by efficient pumps, but pumping alone is hardly sufficient, as the inner metal and glass parts are capable of adsorbing and retaining gases. Adsorbed gases are eliminated by evacuating the tubes while they are heated to high temperatures. Glass tubes are heated by inserting them in a high frequency field. Metal tubes are heated by gas flames. Even with the highest refinement in evacuation, gas may be liberated in the tubes under service. Various types of getters have been developed to remove the last traces of gas.

Thermionic valves are not produced on a commercial scale in India at present. Under a scheme of research sanctioned by the Council of Scientific and Industrial Research, a pilot plant for the production of valves was set up at the University College of Science, Calcutta in 1946 and valves of type 80 full-wave rectifier have been produced (Deb & Sen, *J. sci. industr. Res.*, 1949, 8A, 312). The Government of India propose to start the production of thermionic valves of all types required for radio equipment.

TRANSISTORS

John Bardeen and W. H. Brittain of the Bell Telephone Laboratories announced the invention of transistors in 1948. This revolutionary device is likely to replace the vacuum tube in many of its applications.

In the course of their researches on the surface properties of germanium, Bardeen and Brittain observed that when two thin wire points were placed close to each other on the surface of a crystal and the wires connected through a battery to a large-area contact on the opposite face of the

crystal, a current through one of the wire points can control the current through the other in such a way as to yield a power gain. Though the arrangement is simple and similar in many respects to a "cat's whisker" on a crystal radio set, the behaviour of the germanium crystal is complicated and has defied precise analysis.

A number of firms in U.S.A., *Western Electric Co.*, *Radio Corporation of America*, *General Electric Co.*, and others, have started producing transistors in quantity.

The advantage of a transistor over a valve is that it does not have a filament, is made of a material which is extremely robust, is not subject to variations with temperature, and the size is extremely small. In most circuits, the transistor will do the same job as a vacuum tube while consuming one-thousandth as much power. Its life is predicted to be about 70,000-90,000 hours or approximately ten years.

CAPACITORS

A capacitor or condenser is defined as a circuit element with two conducting surfaces separated by an insulator. The space between the conducting surfaces may be evacuated or it may be filled by a gas, a liquid, or a solid. There are usually a number of different types of capacitors in a receiving set.

The capacitor in conjunction with the inductance forms the tuned circuit and can be designed to have any desired resonant frequency. The capacitor is also used for blocking the flow of direct current but permitting alternating currents to flow. It is also used as a filter for smoothing rectified alternating currents.

There are two classes of capacitors—the variable and fixed.

A variable capacitor is usually an air-dielectric capacitor, characterized by relatively low loss at radio-frequencies. It consists of two sets of parallel plate assemblies, one set fixed and the other moving between the fixed plates. The plates are of brass or aluminium. Brass plates are treated to prevent corrosion under tropical conditions. The spacing between the fixed and the moving plates is adjusted by machined metal spacers.

Capacitor plates are shaped specially to follow a particular law of variation of capacity with the degree of rotation. The variation may be represented by a straight line, a logarithmic curve, or a square law depending upon the needs of the particular circuit.

Mica trimmers are compression capacitors in which one or more plates are interspaced with mica sheets varying in thickness from 1.5 mil to 3 mil. They have a ceramic or a paper laminated phenolic piece as base. Trimmers are generally of low capacity; the capacity can be adjusted over

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a limited range with the help of metal screws which press the plates together or take them apart. Compression capacitors are generally used for adjusting tuned circuits, in which variations occur due to design limitations.

Ceramic trimmers are assembled from ceramic (usually steatite) discs. The surfaces of the discs are spray-coated with a silver compound and the coat later reduced to metallic silver. The trimmer consists of two discs kept slightly apart by a non-ferrous spring. The discs can be rotated and the area of the silvered surfaces which come over one another can be varied.

Fixed Capacitors—Four types of fixed capacitors are in use, viz. moulded mica, ceramic, paper, and electrolytic.

Moulded mica dielectric capacitors are available in two types—foil conducting plates are employed in one type and metal-coated dielectric films are used in the other. Both are relatively small and both have high leakage resistances and low power losses. Plated or silver-mica capacitors consist of mica sheets on which silver is deposited as a closely adherent film.

The foil type of construction is subject to variation in capacity due to air pockets between the plates and the dielectric. "Stacked" mica is used in circuits where a high degree of accuracy or thermal stability is not called for.

"Stacked" mica capacitors are assembled with selected dry mica and metal plates. Aluminium or brass plates, 1.0–1.5 mil thick, are stacked one above the other with mica plates in between. The ends of the metal plates, which project beyond the mica, are soldered or spot-welded together. A metal clamp is fixed around the stack and the assembly subjected to uniform pressure in a press. The two metal ends are soldered to tinned copper wires. The whole capacitor is then impregnated in vacuum with wax and mounted in a phenolic resin or other moulding compound. Stacked mica capacitors are manufactured by *Radio Supply Stores, Calcutta, IRP (Radios) Ltd., Calcutta, and National Ekco Radio & Engineering Co., Ltd., Bombay.*

Silvered mica—An improved form of capacitor, called the Protected Silver Mica Capacitor, is used wherever stability or close tolerance is essential. In this capacitor, the silver electrode or plate is fired on to the mica dielectric by a pyro-chemical process and the capacitance is adjusted by scraping off the excess. The silver electrodes are connected by a thin metallic foil and the stacked pieces assembled with tubular eyelets fitted to the two ends. Leads for making contacts with the plates are also fixed to the tubular rivets. The entire assembly is cleaned, dried, and impregnated with a special blend of wax. A thick layer of wax prevents the capacitor from deterioration under tropical conditions. The capacitors are produced

by *National Ekco Radio & Engineering Co. Ltd.* and, on a pilot plant scale, in the National Physical Laboratory, New Delhi.

Ceramic capacitors are made from hollow extruded tubes of titanium dioxide or similar material, coated inside and outside by silver paint, and fired at a high temperature. The silver plating may be covered with a copper plating and leads soldered to the latter. Ceramic capacitors can be manufactured to any defined positive, negative, or zero temperature coefficient. Their exceptional stability and low power factor make them particularly useful in high frequency circuits.

Ceramic capacitors made from barium and strontium titanates exhibit high dielectric constants at room temperatures. When heated to the Curie point (c. 120°), the dielectric constants increase considerably. Investigations on high dielectric ceramics are under way in the National Physical Laboratory.

Paper capacitors of small sizes are made in cylindrical form. Those of large sizes have a flat form.

Aluminium or tinned copper foils, $\frac{1}{2}$ to 1 mil thick, separated by layers of long-fibred kraft paper, are rolled together into tightly wound cylinders. The foils as well as the paper should conform to rigid specifications. Special winding machines are employed. Winding is preferably carried out in air-conditioned rooms, operators being required to wear sterilized rubber gloves. The foils are staggered slightly with respect to the paper to give non-inductive winding. Small stubs of thicker foils are introduced at appropriate places for electrical contact. Spiral terminals are fixed to the ends by soldering or other means.

The number of layers of paper between the foils is determined by the voltage rating of the capacitor. Generally four to five papers are used for condensers which are required to stand 500 volts d.c.

In large-sized capacitors commonly used in telegraph and telephone circuits, the winding need not be non-inductive. The capacitors are required to stand lower voltages and are assembled in cans filled with pitch or wax and sealed. The terminals are of the metal-to-glass type.

Wound pieces are dried in an oven to drive out moisture and transferred to a heated vacuum chamber. Molten wax is admitted into the chamber to cover the pieces completely. After a few hours, when impregnation is completed, the excess of wax is removed and pieces cleaned. Spiral terminals are fixed and condensers moulded in a suitable compound.

In another process, petroleum jelly is used as impregnant. Since petroleum jelly does not solidify at room temperatures, the capacitors have to be housed inside aluminium containers

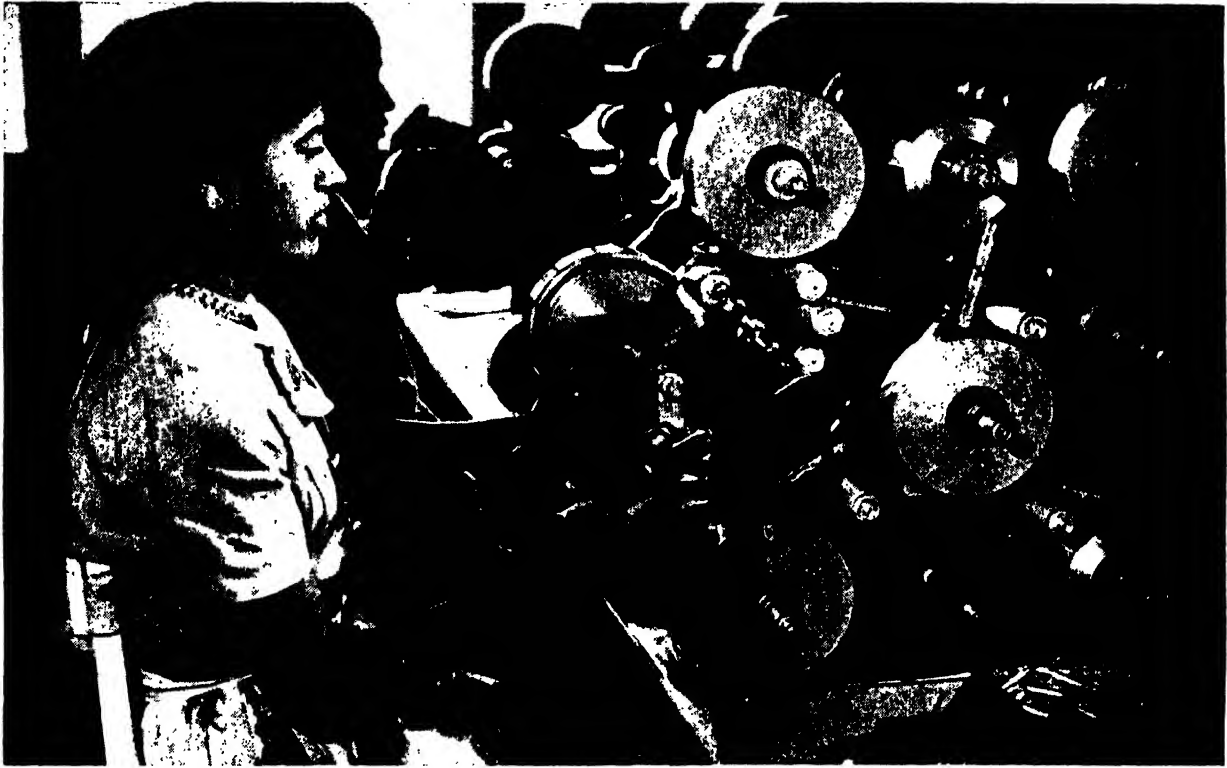


FIG. 51—WINDING OF PAPER CONDENSERS

National Eko Radio & Engineering Co. Ltd., Bombay

with terminals leading out through neoprene-sealed ends. This construction makes the capacitors completely impervious to moisture and they stand rigorous climatic conditions.

Another process developed in Germany makes use of special paper coated with a thin layer of thermoplastic material. The paper is passed through an evacuated chamber containing molten zinc or aluminium and metal particles deposited on the surface. Both sides of the paper are coated for use in low voltage capacitors. The coated paper is rolled into complete cylinders and terminals fixed to the metal coating. The pieces are impregnated and either moulded or encased in cardboard tubes.

Aluminium is reported to have certain advantages over zinc in metal-paper capacitors. In the event of short-circuiting due to pinhole or other defect in the paper, a heavy current flows momentarily through the metallic film and the coating is burnt off at the spot. This clears the short-circuit and the capacitor continues to function without causing damage to the rest of the equipment though a reduction in capacity results. When aluminium is used as coating material, the

high current passing through leads to the formation of aluminium oxide, which is an extremely good insulator.

Electrolytic capacitors—The characteristics of electrolytic capacitors are quite different from those of others.

The capacitor consists of two aluminium foils with an electrolyte between them. One of the foils is oxidized and acts as an insulating film. As in the case of dry cells, the electrolyte is retained in paste form by an absorbing material of high purity. The oxide film forms the dielectric and the two foils form the conducting surfaces. The electrolyte is necessary to maintain the oxide film and to prevent damage due to the break down of the film.

In the semi-dry electrolytic capacitor, the electrolyte is a highly viscous jelly. Present day designs make use of two types of foils, the etched and the plain. Etched foil capacitors are of small size, while plain foil types are bigger because, for a given size, the effective surface area of a plain foil is much less than that of an etched foil, the difference being seven to eight times. Because of the extreme thinness of the dielectric medium,

high capacities can be built in electrolytic capacitors. Depending upon the voltage rating, capacities of the order of 150 to 200 microfarads can be obtained. The cost of manufacture is also low though permissible tolerances have to be large.

The materials used for electrolytic capacitors should be of a high degree of purity and manufacture should be carried out under controlled atmospheric conditions in dust-free rooms and under conditions of "operation theatre" cleanliness.

Electrolytic capacitors are sensitive to variations in temperature. If left unused for a long time, the anodic film has a tendency to dissolve in the electrolyte and the film has to be reformed before putting the capacitor in circuit. Electrolytic capacitors are used in domestic and tele-communication equipments where servicing facilities are available and maintenance schedules can be arranged.

The life of electrolytic capacitors is comparatively limited and the capacitor is one of the items in a radio receiver which has to be replaced even before the valves.

A new type of electrolytic capacitor, the tantalum capacitor, has been recently developed by Messrs. *General Electric Co.*, U.S.A. It is similar to the aluminium electrolytic capacitor in construction. A tantalum foil is employed and a special electrolyte developed by the company ensures a smaller overall size of the capacitor. The anode is formed by the sintering technique. Tantalum powder is moulded into a compact shape and sintered in a vacuum furnace. This gives a porous mass with a relatively large surface area for oxide formation as in etched foil. The temperature range is -55° to $+85^{\circ}$; leakage currents are low and the shelf life long. They are available for operation up to a voltage of about 150 V d.c. The capacitor meets the stringent demands of the defence services.

Research for utilizing high dielectric titania for large capacitors, which can be substituted for electrolytic capacitors, is in progress at the National Physical Laboratory of India. Ceramics have the advantage of robustness and long life as no chemical action is involved for maintaining the capacity.

Paper, stacked mica, silvered mica, and trimmers are manufactured in India. Tests have shown that capacitors produced in India are in every way equal to imported ones, and they have been successfully used in radio receivers. A moulding compound based on shellac has been developed; capacitors moulded in this compound are as good as those encased in aluminium tubes with neoprene-sealed ends.

RESISTORS

Resistors are circuit elements used for limiting the current flow in a circuit or to produce a voltage

drop. They are rated according to their resistance and ability to dissipate power. The values used in radio circuits range from a fraction of an ohm to 10 or more megohms and from less than 1 watt to over 100 watts.

Resistances are classified under two heads—fixed and variable. Among the fixed resistors are wire-wound resistors and composition type resistors.

A *wire-wound resistor* is normally a porcelain tube round which is wound a resistance wire, nichrome or other material, and covered with an inorganic or an organic coating. The inorganic coating is a low-melting enamel frit fired on to the surface to form a close bond with the ceramic tube embedding the wire. Sometimes a cement is used as coating. The hot spot temperature in the wire under operating conditions may be as high as 300° .

Resistors coated with organic materials have to be operated at temperatures not exceeding 125° . Silicones are coming into use as coatings for wire-wound resistors and are known to stand temperatures up to 400° .

Vitreous enamel coated resistors have not been approved as Class I material by the defence services. Hair-line cracks which develop in the coating permit moisture to creep in. Silicone-coated resistors, which are moisture resistant, are coming into more common use, particularly for use in service equipment.

Wire-wound resistances of low power dissipation are wound on ceramic or glass tubes and may be uncoated. Resistances with higher dissipation are used in transmitters, receivers, and amplifiers as bleeders, filament dropping resistances, or voltage dividers.

The process of manufacturing wire-wound resistors developed at the Indian Institute of Science, Bangalore is as follows: Thermal shock-proof porcelain tubes are wound over with nichrome wire of the required gauge. The coil is anchored to the two ends of the tubes by brass or copper clamps. The surface is spray-coated with low melting frit of the same temperature coefficient as porcelain and nichrome wire. Coated resistances are fired in a furnace to allow the frit to melt and flow around the coils of wire and the tubes.

The enamel consists of flint, feldspar, borax, cryolite, fluorspar, sodium nitrate, antimony compounds, oxides of tin, lead, zinc, magnesium, and zirconium; oxides of cobalt, iron, manganese, chromium, nickel, and uranium are added as colorants. The materials are ground, mixed, and melted in a furnace. The molten charge is poured into a tub of water. The frit is ground to a fine powder in a porcelain ball mill with water and clay matter (Chakravarti, *J. sci. & industr. Res.*, 1945, 4, 89).

Composition type resistors consist of finely

divided carbonaceous material mixed with resins or other binders to obtain the specific resistance required. They are used for low power applications. The resistance varies according to changes in voltage, humidity, and temperature. Insulated carbon resistors are enclosed in a moulded case for protection from humidity.

Work on composition resistors has been carried out at the Indian Institute of Science, Bangalore and in the Applied Physics Department, Calcutta University. The resistors developed at the Indian Institute of Science are made of carbon, an inert filler material, such as china clay, talc or asphalt, and a resin (natural or synthetic). Carbon and filler are powdered in a ball mill, mixed with resin, and extruded into rods. The rods are cut into convenient sizes and dried in an oven. They are then cured to polymerize the binder. Hot moulding followed by curing has also been tried. The pieces are tested, painted, and colour-coded by insulating paints.

In the process developed at the *National Ekco Radio & Engineering Co. Ltd.*, Bombay, low-melting frit is employed in place of resin as binding material. Carbon powder and filler are mixed with frit, powdered in a ball mill, pasted in an edge runner with dextrin solution, and extruded into rods. The rods are cut into pieces, dried, and fired in a furnace at 900°. Fired pieces possess good mechanical strength and are more satisfactory than resin-bonded resistors.

The process developed in the Applied Physics Department, Calcutta University is as follows: Powdered graphite is sieved through silk lawn and the particle size of the powder checked by examination under a microscope. It is mixed with water, passed through colloidising mills, and graded by noting the amount of graphite in a measured volume of mixture. Glass rods, 2 to 3 mm. diam., are coated with the mixture and heat-treated in a furnace up to 150°. Coated rods are tested and encased in glass tubes. Resistances from 100 ohms to several megohms have been prepared by this process.

Metallized film resistors are prepared by metal deposition on insulator rods in high vacuum.

Cracked film carbon resistors are prepared by depositing carbon films on porcelain tubes. The surfaces of the tubes are cleaned and etched by sand-blasting. The tubes are placed in a furnace at 900° and a hydrocarbon gas admitted. The hydrocarbon "cracks" at the temperature of the furnace and a film of carbon is deposited uniformly on the rods. The resistance value is determined by the quantity of hydrocarbon admitted into the furnace and the value can be adjusted by scraping off a portion of the film. Coated tubes are moulded in a suitable insulating compound. The resistors can be manufactured to close tolerances and used wherever resistances of high stability, low

temperature coefficient, and long life are required. They are not intended to dissipate power.

Variable resistors—Resistors whose resistance values can be varied for adjustment purposes and which are useful also for dissipating power are of two types: wire-wound and composition. Wire-wound resistors are manufactured by the same process as that employed for fixed resistors. A gap is left in the enamel coating along the length exposing the wire. A moveable metal clamp is fixed round the resistor to make an electrical contact with the exposed part of the coil and any value of resistance within the limits of the total resistance of the unit can be obtained by changing the position of the clamp. Wire-wound variable resistors are made by winding a resistance wire on a cylindrical ceramic former and providing a moving contact of phosphor-bronze pivoted at the centre of the former. The two ends of the coil are anchored to terminals suitably mounted at the circumference. The arrangement is encased in a plastic case. The resistors are of fairly high ohmic value.

Composition type resistors are manufactured over a wide range of resistance values, from 100 ohms to 10 megohms. The tolerance of such resistances is generally $\pm 20\%$.

Composition resistances of the phenolic resin type are usually limited to a maximum power rating of 4 watts. In the simplest form, they consist of circular discs punched from electrical grade, paper-laminated, resin-bonded sheet, c. 1/16 in. thick, coated with graphite. The graphite is dispersed in a volatile medium containing a binder. The solvent is allowed to evaporate and the coating cured in an oven. The element is 'aged' by exposure to a number of humidity cycles in a chamber. The resistance value can be adjusted by varying the proportion of colloidal graphite to the binder in the coating composition.

A process developed by the *National Ekco Radio & Engineering Co. Ltd.*, Bombay, in which colloidal graphite is coated on a suitably treated paper, has given satisfactory results. Aged resistors are remarkably stable.

Varistors—Resistors whose value varies with voltage and/or temperature are called varistors. They are usually made of metallic oxides or other metallic compounds which are sintered in an inert binder, such as clay. They are characterized by extreme sensitivity to voltage and temperature changes.

Low voltage varistors—The classic examples of low voltage varistors or rectifiers are selenium, copper oxide, galena, and carborundum. They are used primarily at low voltages and their resistances are dependent on the direction of the applied voltage.

Thermistors—Resistors of this class consist of mixtures of one or more metallic oxides, such as

ELECTRICAL INDUSTRIES

ferric oxide (Fe_2O_3), nickel oxide (NiO) and titanium dioxide (TiO_2). They are temperature-sensitive and are characterized by high negative temperature coefficients.

TRANSFORMERS

Transformers of various types—power transformers, output transformers, and intervalve transformers—are being produced in India. Winding of transformers is carried out on a cottage industry basis, and small organizations with hand winding machines, each costing c. Rs. 400/-, are producing fairly good transformers. Service shops are generally equipped with winding machines to rewind transformers and chokes.

The transformer consists of a laminated iron core of silicon steel (thickness, c. 0.014 in.). The core is punched out of sheets in the form of 'E' and 'I', and punched sheets are stacked alternately so that there is no air gap when the core is assembled. The cores are painted on one side

with insulating varnish and individual stampings are insulated from each other to reduce losses due to eddy currents.

The transformer coil consists of multi-layer multiple windings, usually one primary winding, one high voltage secondary winding, and two or three low voltage secondary windings. The different windings are insulated from each other. The coil is wound with enamelled copper wire on a former of insulated material, individual layers being insulated by two or three layers of long-fibre kraft paper. The entire coil, after winding, is slipped on to the central leg of the E stampings. E and I stampings are assembled alternately and the assembly clamped down by external clamps or bolts, dried in an air oven, and impregnated with insulating varnish in a vacuum vessel. It is then dried, cured, and rendered 'tropic-proof' by one or two coatings of pitch.

A recent technique of manufacture of high class transformers comprises the following steps:



National Ekco Radio & Engineering Co. Ltd., Bombay

FIG. 52—WINDING OF TRANSFORMER COILS ON AUTOMATIC MACHINES

The core material is of silicon steel in thin strips (< 0.014 in.). The strips are pliable and can be bent into the form of a cylinder whose cross section is a flattened circle. The core is cut exactly in the centre into two halves, the two sections having the shape of the letter C. This type of core is called the C core. Coils are wound, in the manner already described, in two sections and slipped over the two C cores. The two halves are connected and clamped together tightly. The assembly is moulded in a cold setting thermoplastic resin and leads taken out through glass-to-metal seals. The transformer is hermetically sealed or placed in steel cans filled with an insulating compound.

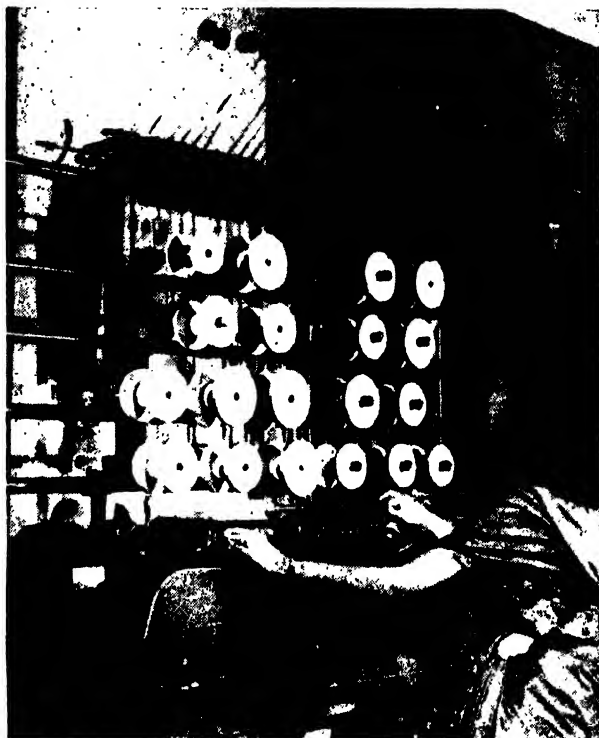
Audio and output transformers are similar to power transformers except that they are designed to operate over a wide range of audio frequencies. They are used as interstage coupling devices in amplifiers and receivers or as matching transformers to couple the output tube of the receiver or amplifier to the loud speaker.

Chokes are similar to mains and audio transformers. They are designed to carry both alternating and direct currents. Iron core chokes are used in smoothing circuits to convert alternating current into direct current. Chokes in conjunction with electrolytic condensers form the smoothing circuits which eliminate 'ripples' present in the rectified current. A choke is a normal feature of receivers or amplifiers which operate on a.c. power supply.

Intermediate frequency (I.F.) transformers are air-cored transformers used in superheterodyne receivers as coupling between the intermediate frequency amplifier and the frequency changer valve on one side and the detector on the other. The coils are wound on an insulated former of phenolic resin or porcelain tube. The coils are of litz wire or stranded enamelled copper wire, twisted and covered with a double layer of silk. The use of litz wire prevents losses due to the skin effect.

Special winding machines are required to wind the coils in what is called basket-winding. This winding reduces the capacity effect of multi-layer windings and thereby the losses at operating frequencies. Present day designs of I.F. transformers use powdered iron core to increase inductance, thereby improving the 'Q' (factor of merit which primarily determines the sharpness of resonance of a tuned circuit) and reducing the number of turns.

I.F. transformers serve as band-pass filters, i.e. they pass a certain band of frequencies in the intermediate frequency range of 465 kc. or thereabouts. The usual band width of I.F. transformers is 5 kc. on either side of the centre frequency.



R. E. M. Co., Bangalore

FIG. 53—TRANSFORMER COIL WINDING MACHINE

I.F. transformers are manufactured in India by *National Ekco Radio & Engineering Co. Ltd.*, Bombay. Their production capacity, however, is adequate to meet their own requirements.

Radio frequency (R.F.) coils are also air-cored and wound with litz wire in the case of medium frequencies and with thick enamelled copper wire in the case of high frequencies. In recent designs, powdered iron cores have been employed to increase the efficiency. Medium wave coils are generally of the basket-wound type; short wave coils consist of a few turns of thick enamelled copper wire spaced apart to reduce capacity effects between turns at high frequencies. The R.F. coil in combination with the tuning capacitor is made to resonate at any given frequency depending upon the position of the tuning capacitor. Tuned circuits are used in superheterodyne receivers for varying the oscillator frequency as well as the resonant frequency of tuned aerial and R.F. circuits.

R.F. coils are produced in India to meet the requirements of the industry. When assembling radio receivers, the distributed capacitance of radio-frequency circuits may vary due to various reasons and it is not always possible to redesign coils or to import large quantities of them. It is

ELECTRICAL INDUSTRIES

usually necessary to effect changes in the inductance to attain efficiency and sensitivity in radio-frequency circuits.

LOUD SPEAKERS

The loud speaker is a device for converting electrical impulses in the audio frequency range into sound waves. It consists of a coil, called the voice coil, fastened to the apex of a paper cone. The coil is located in a magnetic field and carries the audio frequency currents. The action of the magnetic field on the coil current produces a mechanical force which vibrates the paper cone and causes the radiation of sound waves. Loud speakers of the diaphragm type are used in public address systems where large amounts of acoustic power have to be handled.

Development work on loud speakers has been carried out in *Kanodia Electrical Communication Engineering Laboratories*, Calcutta and in the *Provincial Radio Engineer's Laboratory*, Madras. Paper cones have been produced on an experimental scale, but magnets of the Alnico type required for loud speakers have not been made. The *Provincial Radio Engineer's Laboratory*, Madras has produced loud speakers suitable for use in community receivers. Loud speakers are being manufactured from imported magnets by *Philips Electrical Co. (India) Ltd.*, Calcutta.

SWITCHES

Switches form an essential part of electronic equipment. They may be classified into: (1) on-and-off switches, double pole or single pole, and (2) switches used in radio-frequency circuits.

During World War II, Messrs. *Tanna Radio Co. Ltd.*, Bombay, were producing single- and double-pole switches. Production ceased in the post-war period due to competition from foreign countries.

Toggle switches consist of paper-laminated resin-bonded sheets, punched to shape and size, with two or four phosphor bronze contacts mounted in a hollow. A powerful spring with a nickel plated copper or brass cylindrical piece moves up and down either short-circuiting the contacts or opening them.

Wave-band switches are used for operating electronic equipment at different frequencies. They are assembled out of wafers of the required shape and size punched out of electrical grade laminated sheets. Silvered phosphor bronze contact strips are riveted to the wafers, the number of contacts depending upon the circuits to be operated. In the centre of the assembly is a wafer with a shorting strip of silvered phosphor bronze. The wafers are assembled on a rotatable shaft, usually a flat strip, passing through the centre. The shaft can be rotated over 360° and combinations of switching can be achieved by suitably assembling wafers and contacts.

Wave-band switches are not manufactured in India though the technique is comparatively simple. Proper choice of materials is vital to the production of reliable wave-band switches.

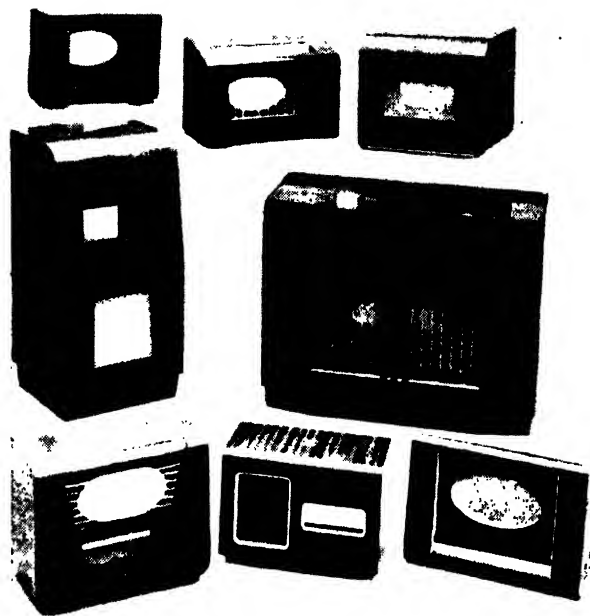
RECTIFIERS

Selenium and copper oxide rectifiers are reliable and easy to mount and connect. Unlike valves which consume current for heating the filaments, they do not consume any current for their operation and they do not get damaged due to vibration. They are mechanically robust as they have no moving parts or filaments. They consist of a film of copper oxide, copper sulphide, or selenium, which has the property of conducting current in one direction and offering high resistance to the flow of current in the reverse direction.



R. E. M. Co., Bangalore

FIG. 54—FABRICATION OF HARDWARE PARTS



Gramophone Co. Ltd., Calcutta

FIG. 55—WOODEN CABINETS FOR RECEIVERS

IRON DUST CORES

Iron dust cores are prepared from powdered iron dispersed in a resin and formed into cylindrical rods or 'torsids' under high pressure. They have low permeability and low eddy current loss at low frequencies and are used extensively in telephony. More recently, cores made of powdered nickel alloy, called Permalloy, and of carbonyl iron dust have come into use. The latter has low hysteresis loss and coercive force.

Both carbonyl iron and iron powder show high power losses at high frequencies. During the past few years, new materials with exceptionally low hysteresis as well as low loss at high frequencies have been developed, particularly by the *Philips Research Laboratory*, under the trade name of *Ferroxcube*.

HARDWARE

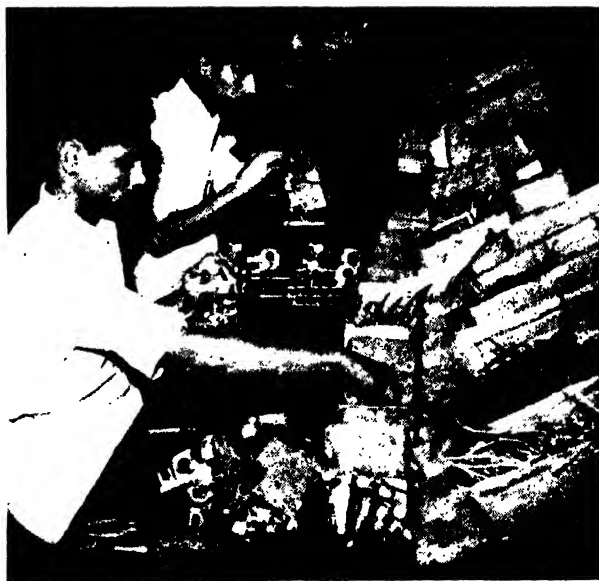
Important among the items of hardware used in radio receivers are chassis, dial-drive drums, cans for I.F. transformers, clamps for power and output transformers and chokes, brackets for dial-drive mechanism, aerial earth terminals, pick-up terminals, and mains panels. The *National Ekco Radio & Engineering Co. Ltd.*, Bombay produces practically all the hardware parts required. The *Radio & Electricals Manufacturing Co. Ltd.*, Bangalore has set up a well-equipped workshop for fabricating all hardware parts. A number

of small firms working on a cottage industry basis produce parts required for radio receivers.

The chassis is usually made of mild steel. It is punched at appropriate places for mounting radio parts and for riveting valve holders. Earth tags are welded to the chassis and the chassis is electroplated with passivated zinc or cadmium. Valve bases, aerial and earth sockets, etc. are then riveted. Coil formers are made from imported former tubes of various diameters. They are cut to size, holes punched, and eyelets fixed. Tag plates are generally used in assemblies for convenience in soldering with external leads of coils. They are cut from bakelite sheet or other suitable insulating material to size and holes punched for fixing tags. Shroud assemblies are used for keeping the laminations intact. They are made from mild steel plate, pressed into sized shape, and electroplated. Tag plates are fixed. Sole backing plates consist of mild steel plates, cut to size and bent at the ends to shape. Mechanical components, such as band switches, control knobs, drive drums, fly wheels, and brass spindles, are usually imported.

CABINETS

Wooden cabinets for receiving sets are made from veneered plywood. The plywood factory at Sitapur (Madhya Pradesh) produces resin-bonded plywood which has proved satisfactory for cabinets. Resin-bonded plywood cabinets made by Messrs. *Toys and Wood Industries*, Travancore for *National Ekco Radio & Engineering Co. Ltd.*, Bombay compare favourably, in all respects



Murphy Radio of India Ltd., Bombay

FIG. 56—SUB-ASSEMBLY SECTION FOR R. F. COILS



National Ekco Radio & Engineering Co. Ltd., Bombay

FIG. 57—SUB-ASSEMBLY SECTION FOR WAVE CHANGE SWITCHES

except the finish, with imported cabinets. The *Gramophone Company Ltd.*, Calcutta has set up a wood-working section, in which cabinets of excellent quality are produced. There are many small establishments for making cabinets and catering to the needs of assemblers in Delhi, Calcutta, and Bombay. The cabinet industry is well established in this country.

Wooden cabinets are usually employed for housing only expensive sets. Moulded cabinets of phenol-formaldehyde and polystyrene are used for cheaper sets. Thermo-setting and thermo-plastic materials stand tropical conditions fairly well.

Messrs. *Indian Plastics Ltd.*, Bombay and *Philips Electrical Co. (India) Ltd.*, Calcutta have installed hydraulic presses of 900 and 1,000 tons capacity to produce cabinets of normal size. The moulds required are not produced in India. So far as is known there is no workshop which is equipped for making such moulds. Moulds are expensive and to bring the cost of cabinets to a

reasonably low level, production should be organized on a mass scale.

THE INDIAN INDUSTRY

The radio receiver industry in India, which is of recent origin, is largely confined to the assembly of manufactured components. The setting up of low power, medium wave broadcast transmitters in Bombay and Calcutta in 1927 provided the stimulus for the manufacture of receivers in India. The inauguration of the broadcasting service in July 1927 gave a further impetus to the manufacture of parts and components, receiving and transmitting sets, and public address amplifiers. Many concerns in Bombay, Calcutta, and other cities started assembling receivers, low power transmitters, and audio-amplifiers from parts and components imported from foreign manufacturers. Locally assembled straight receiving sets proved quite satisfactory for the reception of Indian broadcasts.

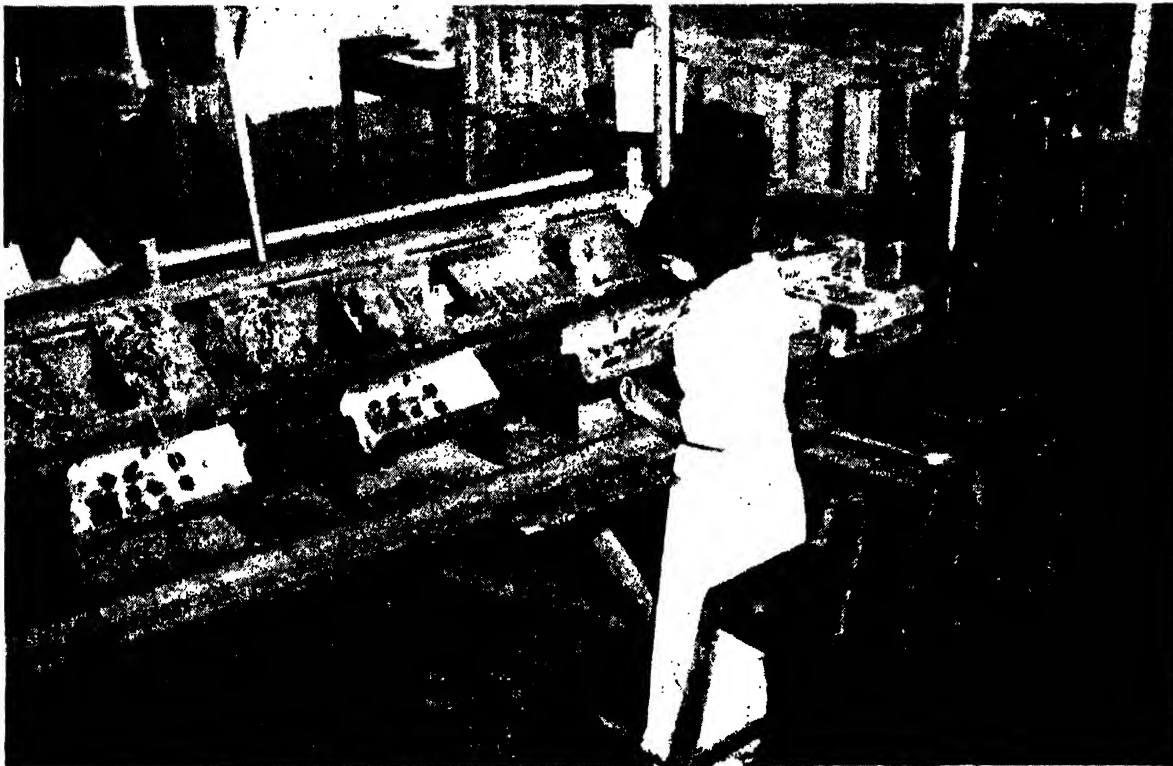
The development of the superheterodyne receivers during the period 1929-1939 led to the

almost complete suppression of 'straight' receivers. Indian producers turned their attention to the assembly of superheterodyne sets. Some of these sets contained a number of components made in India. The outbreak of World War II gave a set-back to the assembly industry.

An investigation into the needs of the radio equipment manufacturing industry was taken up in 1942 by the Government of India. Spare parts for the maintenance of military equipment were difficult to obtain and Government encouraged scientific institutions and private industry to develop processes and to undertake the manufacture of components from materials available in India. The Council of Scientific and Industrial Research sponsored a number of research projects in scientific institutions and several concerns for the manufacture of radio components came into being. The *National Radio & Engineering Company*, Bombay, which was started in 1940, entered into technical collaboration with Messrs. *E. K. Cole & Co.*, London and under the name *National Ekco Radio & Engineering Co. Ltd.*, Bombay, this firm has been engaged not only in the manufacture of components but also in the assembly of receiving sets. Contractual agreements with

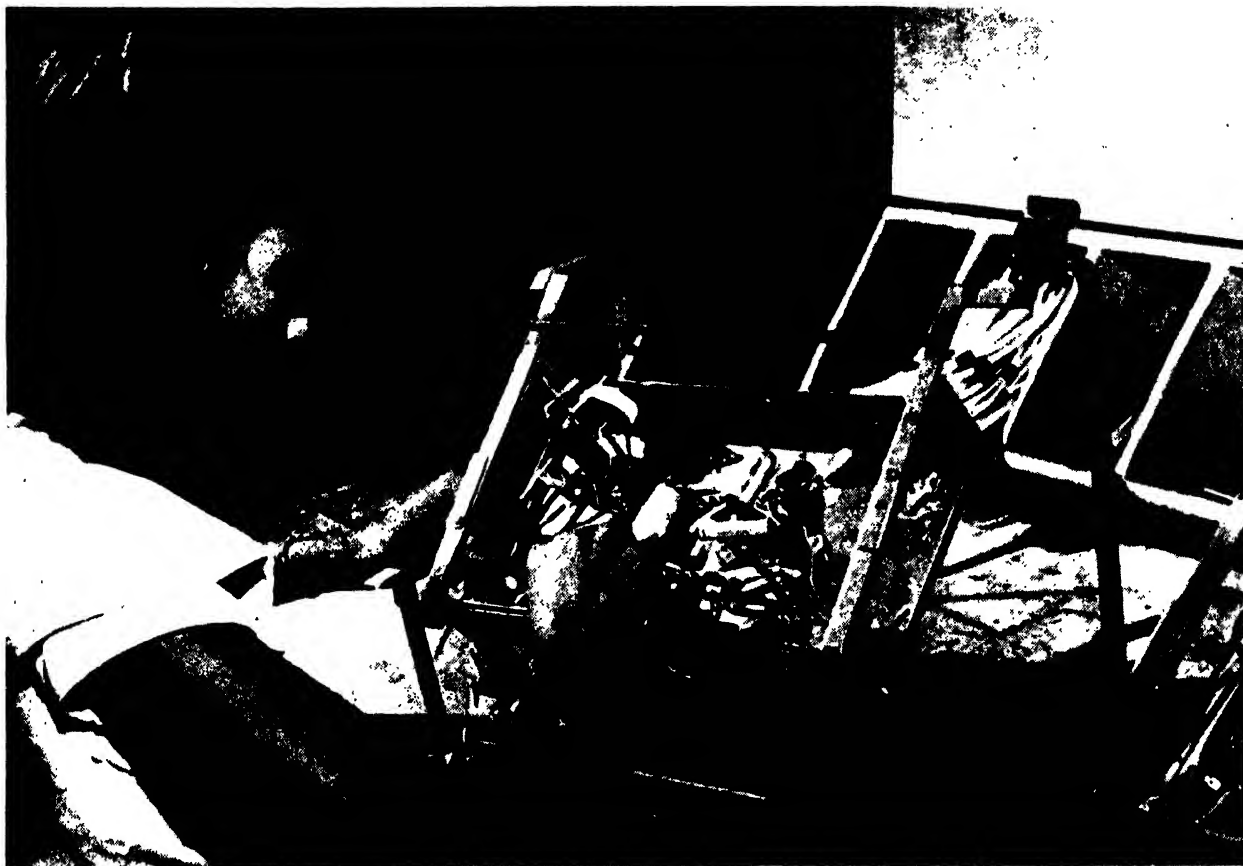
foreign firms have been entered into by Messrs. *Indian Plastics Ltd.*, Bombay (with *Layland Instruments Ltd.*, London) and *Radio & Electricals Manufacturing Co. Ltd.*, Bangalore (with *International General Electric Co.*, New York). Messrs. *Murphy Radio of India Ltd.*, Bombay has set up an assembly plant for producing Murphy sets. Messrs. *Resa Radios Ltd.*, Madras, *Eastern Electronics Ltd.*, Faridabad, *IRP (Radios) Ltd.*, Calcutta and a few other concerns produce sets which are comparable both in quality and in price with imported sets. At present, there are 15 organized factories in the country for the production of radio receivers. In addition, assembly of radio sets is also being carried out by a large number of unregistered individual firms and technicians.

Community receivers.—With the object of providing facilities in villages for people to listen to broadcasts, a number of States have taken steps to instal 'community receivers' in villages. The Madras Government has installed nearly 1,500 receivers in various parts of the State. Other States taking steps to instal community receivers are Delhi, Bombay, Bihar, and Kashmir. The total number of such receivers is about 5,000. The



Radio & Electricals Mfg. Co. Ltd., Bangalore

FIG. 58—MAIN ASSEMBLY LINE : FIRST STAGE IN RECEIVER ASSEMBLY



National Ekco Radio & Engineering Co. Ltd., Bombay

FIG. 59—MAIN ASSEMBLY LINE : COMPONENTS ARE ADDED

receivers are operated on 6-volt car batteries. The batteries need continuous attention and periodical replacement. Recently, experiments have been carried out by the Bombay Provincial Broadcasting Organization on the utilization of dry battery operated receivers for installation in villages. Tentative designs have been prepared and a few receivers have been installed by the All India Radio round about Delhi and in Kashmir. Specifications for community receivers operated on dry batteries have also been drawn up.

Assembly—The radio receiver assembly industry in India is well organized. Mass production techniques have been adopted. The assembly is split up into a number of sub-assemblies, each sub-assembly being split up in its turn into a few individual operations. Components and sub-assemblies are tested thoroughly before they meet the main line.

Before starting the assembly, pre-production models of a particular design of the set are built by the production department and the sequence of operations is worked out to ensure continuity of work. The number of sets to be made is deter-

mined and tested parts issued to each operative to meet the day's production.

Sub-assemblies, such as connection of wires to wave change switches and trimmers and preparation of wires of pre-determined lengths, are carried out separately on benches placed adjacent to the main production line. The chassis is fed at one end of the line on a movable cradle which enables the chassis to be adjusted to any angle. Component wires, screws, etc. are kept in trays within reach of the worker. Automatic nut runners driven by compressed air are suspended over work benches so that nuts and screws can be driven home without fatigue. Earthing wires are spot-welded to the chassis. Provision is made for inspection at intermediate stages to ensure that connections are faultless. Valves are inserted in appropriate sockets and the cradle removed.

The assembly table is about 3 feet high. A long row of shelves for accommodating components occupies the centre of the table. Sockets are placed under the shelves for connecting soldering irons.

Inspection points are provided at suitable intervals in the assembly line to check solder joints and connections. Provision also exists for removing any defective chassis from the line.

After fixing the components to the chassis, the set is inspected by a trained inspector and sent to the first testing station where electrical circuits are tested consecutively in the rectifier section, audio section, intermediate frequency section, and radio-frequency section. The electrical output without the loud speaker is tested on the bench itself and the performance checked against standards fixed by the design department. Sets which are not up to the standard are sent to repairers who diagnose the defects and rectify them. The sets are put into the cabinets to which dials and loud speakers have been fixed. In some factories, the sets are put on what is called a 'heat-run' for a couple of hours. A certain percentage of the assembled sets is tested on stations and approved sets are put into cardboard cartons and sent to the stores.

The equipment used in the assembly of radio

receivers include: power presses for fabricating sheet metal parts; capstan lathes for turned parts; coil winding machines for power transformers, output transformers, I.F. transformers, and coils; riveting machines for assembling tube sockets, tag strips and terminals; spot welders for making ground connections; and nut runners operated with compressed air.

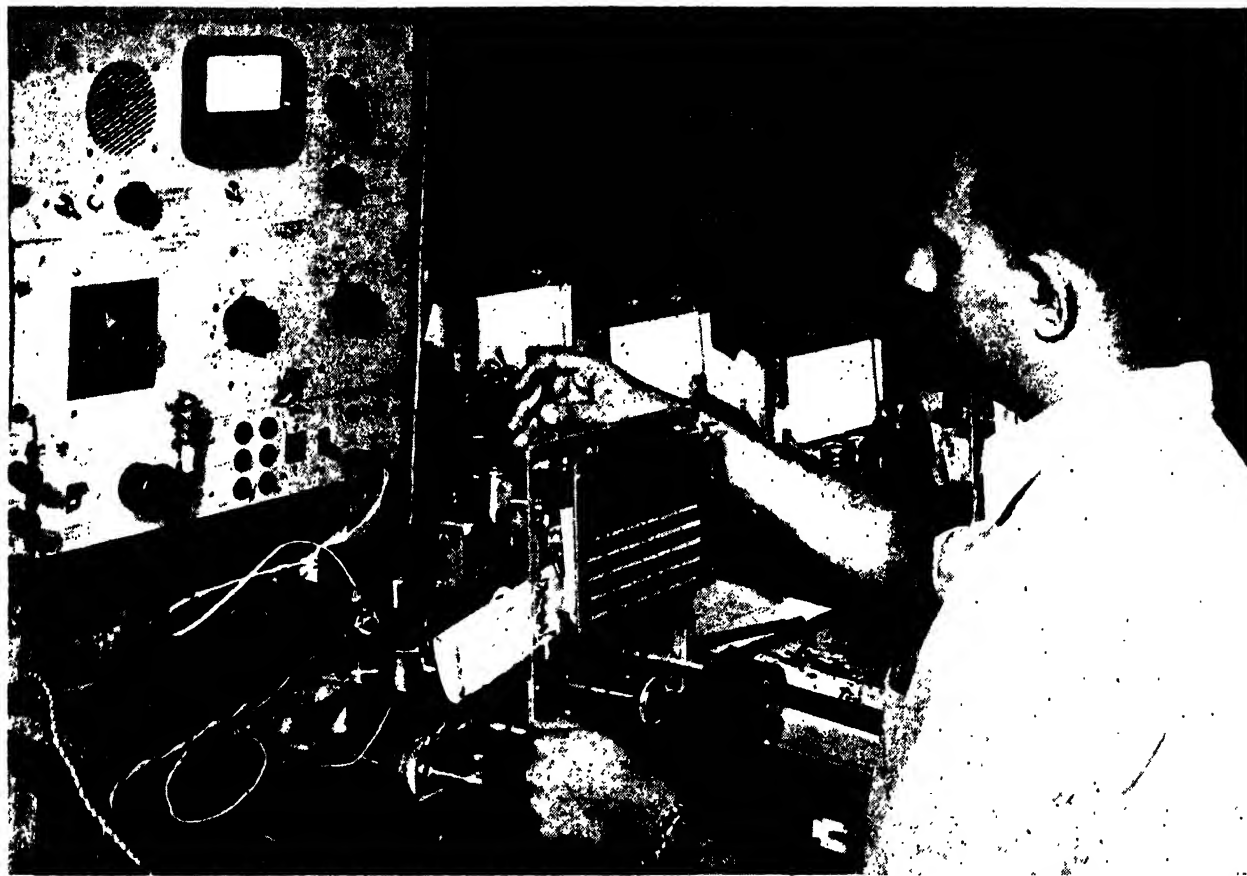
Testing—The Indian Standards Institution has issued draft specifications for radio receivers and components. The National Physical Laboratory of India, New Delhi tests commercial radio receivers and issues certificates.

Production—The following types of receivers and components are produced in India: domestic radio receivers (a.c., a.c./d.c., dry battery operated), village community sets, amplifiers, and inter-communication equipment. Messrs. *National Ekco Radio & Engineering Co. Ltd.*, Bombay; *Tesla (India) Radio Manufacturing Co. Ltd.*, Bombay; *Murphy Radio of India Ltd.*, Bombay; *Indian Plastics Ltd.*, Bombay; *Radio & Electricals Manufacturing Co. Ltd.*, Bangalore; *Resa Radios*



National Ekco Radio & Engineering Co. Ltd., Bombay

FIG. 60—FIXING THE BACKING PLATE OF THE ASSEMBLED RECEIVER



National Ekco Radio & Engineering Co. Ltd., Bombay

FIG. 61—TEST PANEL OF THE MAIN ASSEMBLY LINE

Ltd., Madras; Philips Electrical Co. (India) Ltd., Calcutta; G.E.C. of India (Manufacturing) Ltd., Calcutta; Gramophone Company Ltd., Calcutta; IRP (Radios) Ltd., Calcutta; Hindusthan General Electrical Corporation Ltd., Nirsachatty (Dt. Manbhum; Radiola Corporation, Delhi; Eastern Electronics Ltd., Faridabad; Moolchandani Electrical and Radio Industries Ltd., Faridabad; and Patiala Electronics Ltd., Patiala—are the major organized producers.

Table 79 gives the production of radio receiver sets in India.

TABLE 79—PRODUCTION OF RADIO RECEIVERS

| | Installed capacity (no.) | Output (no.) |
|------|--------------------------|--------------|
| 1947 | 8,000 | 3,033 |
| 1948 | 24,000 | 25,000 |
| 1949 | 22,000 | 16,838 |
| 1950 | 77,500 | 44,340 |
| 1951 | 87,200 | 82,786 |
| 1952 | 193,100 | 71,495 |

According to the Planning Commission, the annual production is likely to increase to about 350,000 sets by 1955-56.

Table 80 gives the Statewise distribution of domestic receivers in 1952 on the basis of licenses issued by the Directorate General of Posts and Telegraphs.

Imports—Tables 81 and 82 give imports of radio receiver sets and components into India.

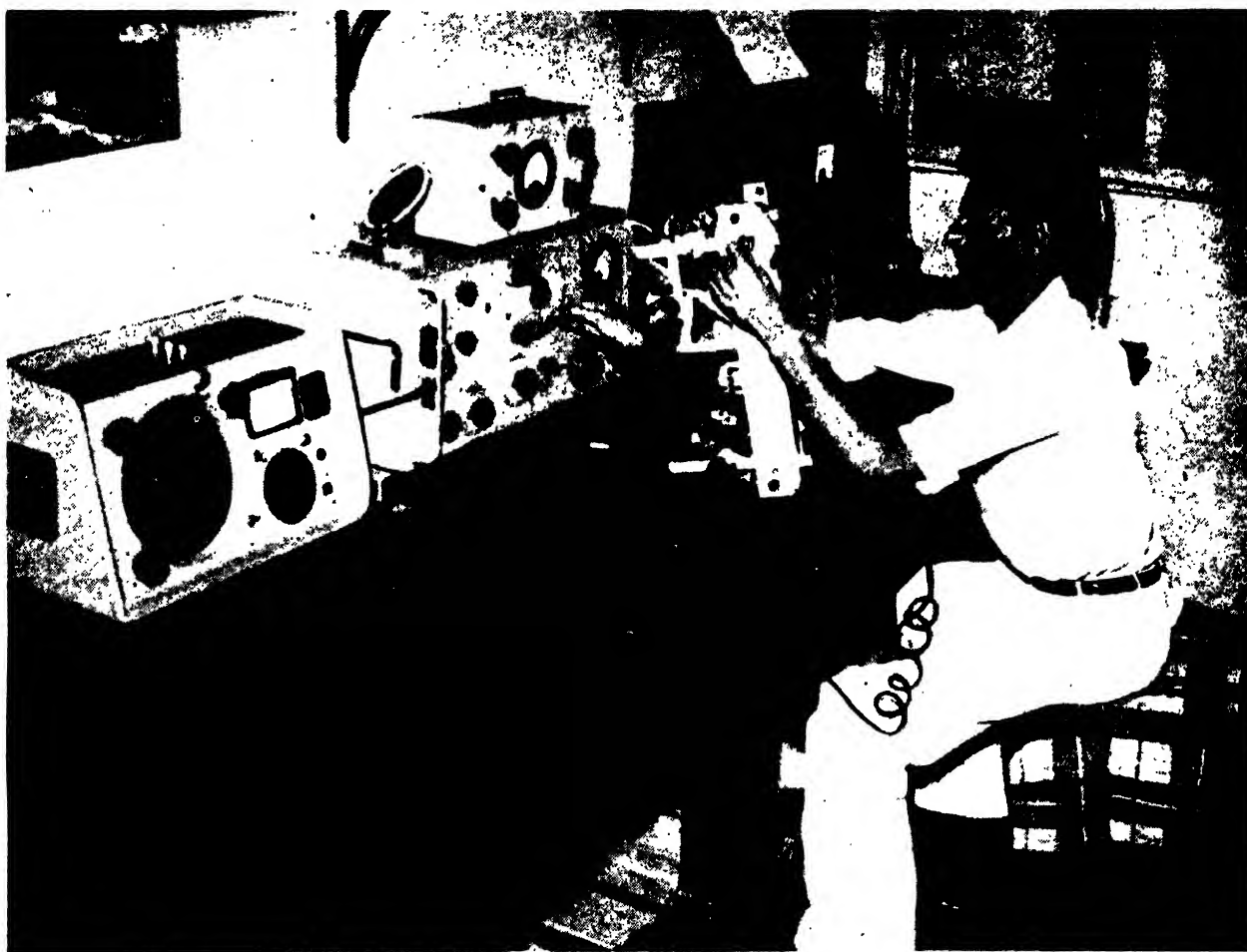
Imports of complete receivers, valves, component parts, amplifiers, and loud speakers are subject to a preferential revenue duty of 44% *ad valorem* for British manufactured articles and 50% *ad valorem* for articles manufactured in other countries except Burma. Articles from Burma are subject to a duty of 20% *ad valorem*. Imports of combination radio phonographs are subject to a preferential revenue duty of 48% *ad valorem* for articles of British manufacture and 54% *ad valorem* for articles from non-British countries except Burma. Wireless transmission apparatus are subject to a preferential import revenue duty of 25% *ad valorem* for British

TABLE 80—STATEWISE DISTRIBUTION OF DOMESTIC RECEIVER LICENCES IN 1952

| Licences | | Licences | |
|-------------------|----------|------------------|----------|
| Bombay | 1,62,045 | Madhya Bharat | 9,370 |
| Madras | 1,10,505 | P.E.P.S.U. | 9,336 |
| West Bengal | 94,866 | Assam | 7,763 |
| U.P.* | 75,702 | Orissa | 5,428 |
| Punjab | 40,120 | Ajmer | 2,700 |
| Delhi | 33,995 | Bhopal | 1,656 |
| Bihar | 32,129 | Kutch | 1,102 |
| M.P.* | 25,469 | Himachal Pradesh | 946 |
| Mysore | 23,215 | Coorg | 273 |
| Hyderabad | 20,932 | Tripura† | 212 |
| Rajasthan | 13,637 | Manipur | 101 |
| Travancore-Cochin | 12,205 | | |
| Saurashtra | 10,853 | | |
| | | Total | 6,94,560 |

Including parts of Vindhya Pradesh

Including N.E.F. Agency



Murphy Radio of India Ltd., Bombay

FIG. 62—TESTING SECTION : ASSEMBLED RECEIVERS ARE TESTED FOR SENSITIVITY



National Ekco Radio & Engineering Co. Ltd., Bombay

FIG. 63—ASSEMBLED AND TESTED SETS BEFORE LEAVING THE MAIN ASSEMBLY LINE

TABLE 81—IMPORTS OF WIRELESS APPARATUS AND PARTS THEREOF
(Qty in numbers and val. in lakh Rs.)

| | Complete receivers | | Valves | | Other components | Total |
|-----------------------|--------------------|--------|---------|-------|------------------|--------|
| | Qty | Val. | Qty | Val. | Val. | val. |
| 1936/37-1938/39 (av.) | 38,201 | 26.38 | 75,232 | 1.79 | 13.18 | 37.83 |
| 1939/40-1943/44 (av.) | 31,856 | 28.96 | 104,003 | 2.55 | 7.96 | 39.47 |
| 1944-45 | 895 | 1.51 | 56,603 | 2.18 | 9.53 | 13.22 |
| 1945-46 | 5,982 | 7.04 | 223,333 | 4.03 | 14.95 | 26.02 |
| 1946-47 | 107,114 | 169.58 | 162,517 | 3.76 | 27.37 | 200.71 |
| 1947-48 | 192,172 | 288.40 | 308,407 | 9.15 | 63.93 | 361.48 |
| 1948-49 | 42,443 | 76.98 | 317,892 | 8.39 | 40.78 | 125.76 |
| 1949-50 | 43,355 | 71.66 | 248,939 | 8.33 | 69.67 | 149.66 |
| 1950-51 | 16,137 | 25.74 | 542,923 | 13.67 | 98.52 | 137.93 |
| 1951-52 | 29,121 | 52.64 | 801,583 | 22.64 | 131.62 | 206.90 |
| 1952-53 | 19,286 | 36.09 | 567,825 | 16.31 | 97.50 | 149.91 |

† Av. figure for the quinquennium 1934/35-1938/39

TABLE 32—IMPORTS OF WIRELESS RECEIVERS AND COMPONENTS IN 1951-52
(Qty in numbers and val. in lakh Rs.)

| | Complete receivers | | Valves | | Other components | Total val. |
|-------------------|--------------------|-------|---------|-------|------------------|------------|
| | Qty | Val. | Qty | Val. | Val. | |
| From U.K. | 16,813 | 32.41 | 487,928 | 14.41 | 87.84 | 134.66 |
| „ U.S.A. | 1,176 | 1.89 | 151,323 | 3.97 | 21.09 | 26.95 |
| „ Netherlands | 3,157 | 8.55 | 147,087 | 3.75 | 22.69 | 45.29 |
| „ other countries | 7,975 | 9.79 | 15,245 | 0.51 | | |
| Total | 29,121 | 52.64 | 801,583 | 22.64 | 131.62 | 206.90 |

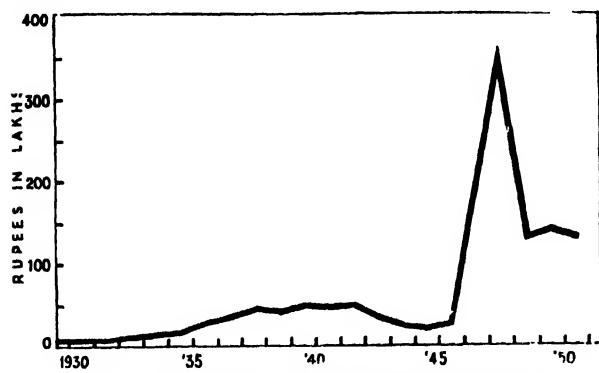


FIG. 64—IMPORTS OF WIRELESS APPARATUS

manufactured articles and a duty of $37\frac{1}{2}\%$ *ad valorem* for apparatus manufactured in non-British countries except Burma.

Switchgear

Switches are devices employed for making and breaking electrical circuits under normal conditions and are operated manually. They are distinguished from circuit breakers which function under abnormal conditions, such as overloads.

Apart from the numerous kinds of snap switches, push button switches, and instrument and control switches, the switches in common use are: knife switches, disconnecting switches, and oil switches.

The knife switch may be single-, double-, or triple-pole, single- or double-throw, fused or plain, front-connected or back-connected. There are special types, such as field discharge switches, motor starting switches, and quick break switches. Knife switches are available in capacities up to 20,000 amp. and 750 volts.

The disconnecting switch, also called a disconnect, is a type of knife switch used primarily to isolate apparatus for inspection, repair, or changing connections. It is used for opening the circuit after the current has been interrupted by other means.

In the oil switch, the live parts are surrounded by oil kept in a tank. Oil switches are manually

operated and are not intended to be opened under other than normal load.

Circuit breakers—A circuit breaker is a safety device for opening electrical power circuits under abnormal load conditions. Ordinary switches cannot be used for this work as they are not designed to extinguish the arcs resulting from circuit breaking. Circuit breakers are operated manually or automatically and are located in special positions of circuits. They are installed in generator leads, feeders, bus ties, motor leads, etc.

Two types of circuit breakers are commonly employed under service conditions—air break and oil break types. The air break type is used principally for d.c. circuits up to 600 volts. It consists of stationary contacts mounted on a vertical panel, a movable contact closed against a heavy spring by a handle, a trip to release the latch, and carbon auxiliary contacts which take the arc when the breaker opens. The breaker is closed by hand and opened by series overload trip coils. A new type of air circuit breaker is the Deion breaker used in a.c. circuits. The arc produced soon after the circuit breaks is deflected by magnetic fields into a deionizing chamber and split up into a number of short arcs which are quenched during a few cycles.

The oil immersed circuit breaker is generally used in a.c. circuits. The arc is quenched by oil as the voltage passes through the zero point. The contacts are opened under oil by a rod extending through the cover of the case and may be operated by hand, motor, or solenoid. In the closed position, the operating arm is tensed by a heavy spring which produces a rapid opening of contacts when released. Oil breakers based on the deionizing principle are also in use. Special types of circuit breakers employing various means, such as oil impulses and pressure chambers, to extinguish the arc have been developed.

Fuses—Fuses are used in low voltage electric circuits for protection against overloads and for circuit breaking. The fuse is 'blown out' when the current exceeds the rated value. The time delay

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in the blowing up is inversely proportional to the current. The fuse ordinarily consists of a measured length of conductor of such resistance that when the current flowing through exceeds the safe limit, the fuse melts and breaks the circuit. In some high capacity fuses, the fuse case contains a powder which helps to extinguish the arc which follows the blowing of the fuse element. Other types of fuses are: cartridge fuses, explosion fuses, thermal overload fuses, iron-clad fuses, etc.

Switchboard—A switchboard is an arrangement which permits the varying of connections between a number of electric circuits. The fundamental requirements of a switchboard are: safety to operating personnel; economic operation; flexibility; and rugged construction. Switchboards may be grouped under the following types: (1) direct control panel type; (2) remote mechanical control type; (3) direct control truck type; and (4) electrically operated type (Van Nostrand, 1428).

Direct control switchboards are used for low and medium capacity installations where low cost is the prime consideration. They are fitted with circuit breakers, disconnecting switches, instruments, etc. mounted directly on the board. In the 'dead-front' type, switches and circuit breakers are mounted on the rear of the board; in the 'live-front' type, they are mounted on the front.

Circuit breakers in remote control boards are mounted separately from the board and are operated mechanically by controls on the board. This ensures safety for the operating personnel.

In the truck type switchboard, the equipment is mounted in a steel compartment from which it can be withdrawn for inspection and servicing. All high voltage parts are enclosed and interlocks are provided for safety. Switchboards of this type are used in industrial applications up to 15,000 volts.

Circuit breakers and other high voltage equipment in electrically operated switchboards are located separately from the board and controlled by solenoids or motor operated devices.

Switchboard panels are made of marble, slate, ebony, asbestos, or steel.

Switchboard equipment includes one or more of the following components: circuit breakers, disconnecting switches, voltmeters, ammeters, watt-hour meters and other operating instruments, and relays; bus construction is provided for connecting various circuits. Switchboards are manufactured both as complete units and as wired units requiring minimum connections in the field.

THE INDIAN INDUSTRY

Switchgear factories are located in Calcutta, Bombay, Madras, Bangalore, and Travancore-

Cochin. The principal firms engaged in this industry are: *Associated Electrical Industries Mfg. Co. Ltd.*, Calcutta; *Electric Construction & Equipment Co. Ltd.*, Calcutta; *General Electric Co. of India Ltd.*, Calcutta; *British India Electric Construction Co. Ltd.*, Calcutta; *India Electric Works Ltd.*, Calcutta; *Crompton Parkinson (Works) Ltd.*, Bombay; *Radio & Electricals Ltd.*, Madras; *Mysore Electrical Industries Ltd.*, Bangalore; and *Electrical and Allied Industries (Travancore) Ltd.*, Kundara.

The following types of isolating switches are produced in India:

(1) Triple pole, gang operated, tilting post, and rural distribution air break switches (up to 200 amp. and 33 kV). These switches consist of three post type insulators per phase. The two outer ones are fixed and the central one, which carries the moving contact, is tilted by a rod mechanism. The complete switch assembly is constructed for mounting on round or rail type H poles. They are suitable for isolating both distribution lines and distribution transformers (off-load).

(2) Single rotating, centre post, triple pole, and gang operated isolating switches (up to 600 amp. and 132 kV). These isolators consist of three stacks of post type insulators per phase mounted on a channel base. The outer stacks are fixed and carry spring-loaded contact jaws for connection to the transmission lines; the central stack carries the copper contact blade of rectangular or tubular section isolated by a tubular connecting and operating rod. Some are provided with interlocked earthing switches on each phase and operating boxes housing auxiliary switches and Castell interlocks. These isolators are normally used at sub-stations and are suitable for mounting in upright or underhung horizontal positions on steel or R.C. structures. Arcing horns are provided on isolators intended for breaking magnetizing transformer currents.

(3) Double rotating, centre post, triple pole, gang operated isolating switches (up to 600 amp. and 132 kV). These isolators are of similar construction to single rotating ones, except that they consist of five stacks of post type insulators per phase. The second and fourth stacks are rotating and carry copper contact blades, while the outer and the central stacks are fixed and carry spring-loaded contact jaws for connection to transmission lines. Each half of the isolator can be operated independently.

(4) Triple pole, tilting blade, horn gap, gang operated, isolating switches (600 amp., up to 132 kV). These switches consist of three stacks of post type insulators per phase mounted on a channel base; the moving contact blades operate in a vertical arc and provide a single break.

During the final phase of the switching on operation the moving blades rotate within the fixed contacts through 90° thereby providing positive locking and automatic cleaning of contact surfaces. The operating mechanism is similar to that in single and double rotating isolators. They are mounted in upright position on steel or R.C. structures and are primarily intended for making and breaking transformer magnetizing currents. They are of more robust construction than single and double rotating isolators; they are also more expensive.

The technical details of the high voltage air break switches of rural and feeder type produced by the *Radio & Electricals Ltd.*, Madras are given below :

| | 11 kV. switches, rural type | 33 kV. switches, feeder type |
|--------------------------------|----------------------------------|--|
| Operating voltage | 11,000 V between phases | 33,000 V between phases |
| Current rating | 200 amp. | 200 amp. |
| No. of insulators | 2 per phase | 3 per phase with centre post rotating and carrying double contact blade with contact jaws on fixed insulator posts |
| Bearing and bushes | Gun metal | Gun metal |
| Contacts | ARNA patent-rated up to 200 amp. | ARNA patent-rated up to 200 amp. |
| Distance between phase centres | 2 ft. 10 in. | To suit users' requirements |
| Mounting height | 20-22 ft. from ground | 20-22 ft. from ground |
| Insulators | Post type | Post type |
| Dry flash-over | 85 kV guar. min. | 180 kV guar. min. |
| Wet flash-over | 55 kV do. do. | 120 kV do. do. |
| Puncture voltage | 150 kV do. do. | 170 kV do. do. |
| Impulse flash-over | 135 kV do. do. | 300 kV do. do. |
| Leakage distance | 13 in. | 34 in. |

Other items of switchgear manufactured in India include: knife switches (single, double or triple pole, single or double throw, front connected or back connected), iron clad switches (250-500V double or triple pole), oil circuit breakers (up to 400 amp.), d.c. rotor starters (up to 100 h.p.), and porcelain fuse units.

Component parts of switches are made with the help of standard machine tools, such as centre lathes, combination turret and capstan lathes, and milling and drilling machines. Bases are made of mild steel plates cut to size in a guillotine, folded, cut to size in a cold saw machine, and welded with other details to form a rigid structure.

All welded parts are heavily galvanized for protection against weather. Almost all the components required for switchgear are produced in the country. Instruments required for switchboards are mostly imported.

Statistics relating to the production of switchgear in India are not available. The annual requirements of switches and fuses are estimated at 400,000 (number) and that of circuit breakers, 25,000. Figures in respect of other items are not available. The Panel on Electrical Machinery and Equipment recommended in 1947 the production of switchgear, except circuit breakers, of the value of Rs. 2 crores per annum during the first five years; during the second five years, the Panel recommended the manufacture of all types of

switchgear, including circuit breakers with a rupturing capacity of 250 kVA, of the value of Rs. 4 crores per annum (*Rep. Panel on the Development of Electrical Industries*, 1947, 25).

Imports—Table 83 gives the imports of control and switchgear into India. Table 84 gives the imports of switchboards other than telegraph and telephone boards.

Switchboards are imported mainly from U.K. Table 85 gives the imports of switchgear and switchboards from U.K.

Imports of electrical control and transmission gear, designed for use in circuits of less than 10 amp. and not exceeding 250 volts, are subject to a

ELECTRICAL INDUSTRIES

TABLE 33—IMPORTS OF CONTROL AND SWITCHGEAR INTO INDIA

| | Val. (lakh Rs.) |
|-----------------------|--------------------|
| 1934/35-1938/39 (av.) | 55.43 |
| 1939/40-1943/44 (av.) | 57.78 |
| 1944-45 | 77.71 |
| 1945-46 | 95.01 |
| 1946-47 | 115.99 |
| 1947-48 | 179.07 |
| 1948-49 | 268.14 |
| 1949-50 | 450.17 |
| 1950-51 | 370.22 |
| 1951-52 | 417.31 |
| 1952-53 | 548.36 |

TABLE 34—IMPORTS OF SWITCHBOARDS OTHER THAN TELEGRAPH AND TELEPHONE BOARDS

| | Val. (lakh Rs.) |
|-----------------------|--------------------|
| 1934/35-1938/39 (av.) | 4.25 |
| 1939/40-1943/44 (av.) | 2.62 |
| 1944-45 | 2.75 |
| 1945-46 | 5.29 |
| 1946-47 | 6.12 |
| 1947-48 | 4.28 |
| 1948-49 | 18.31 |
| 1949-50 | 24.67 |
| 1950-51 | 15.69 |
| 1951-52 | 10.44 |
| 1952-53 | 5.26 |

TABLE 35—IMPORTS OF SWITCHBOARD FROM U.K.*

| | Qty (tons) | | | | | Val. (£) | | | | |
|--|------------|-------|-------|--------|--------|----------|---------|-----------|-----------|-----------|
| | 1946 | 1947 | 1948 | 1949 | 1950 | 1946 | 1947 | 1948 | 1949 | 1950 |
| Starting & controlling gear for electric motors | 448 | 782 | 590 | 14,387 | 10,970 | 218,470 | 389,416 | 377,414 | 383,400 | 303,031 |
| Switchgear & switchboards (other than telegraph & telephone) | 1,971 | 1,907 | 2,809 | 88,705 | 85,499 | 646,664 | 705,963 | 1,167,304 | 2,085,140 | 1,931,080 |

* Tr. U.K.

revenue duty of 37½% *ad valorem* with a preferential rate of 25% *ad valorem* for articles manufactured in U.K.

Telegraph and Telephone Equipment

In communication by telegraph, the message or signal is transmitted by electrical pulses according to a code. The operator sends a certain combination of pulses for each letter of the message which is transcribed into the original message at the receiving end. A keyboard similar to that of a typewriter is provided in Automatic Telegraph for sending messages. The striking of the keys is transformed into electrical pulses (according to the code) and a machine at the receiving end selects the letters and types out the message. The message may be transcribed to a punched tape and transmitted automatically. The transmission may be simultaneous to different stations.

In its simplest form, the telegraph consists of a battery, a key, and a sounder. The telegraph key is a switch, operated by hand. The sounder is similar to a relay, the difference being that the former gives an audible signal. In the closed circuit system, the current flows when no message is being sent. Several stations may be connected

in series with a common battery. When the key is pressed, the circuit is interrupted and the sounders move to spacing stop. In the double current system, the current flows in one direction for a signal and in the opposite direction for a space. The system allows transmission in either direction. In the Duplex system, an arrangement is provided for simultaneous transmission in both directions.

Two printing telegraph systems, differing in details rather than in principle, are in use. These are the Baudot system and the teleprinter. In the former, five electrical pulses in various combinations are transmitted from a special keyboard distributor, operated by a skilled worker; the receiving mechanism prints the message on a paper tape. The transmitter of a teleprinter consists of a keyboard similar to the typewriter keyboard. When a key is pressed, a set of 7 pulses consisting of a start, 5 pulses according to the code, and a stop are transmitted to the line. The start and the stop pulses are common to all sets; the various combinations of the 5 intermediate pulses determines the letter or figure to be printed. The message is directly printed at the receiving end either on a paper tape or roll.

A higher speed of working is possible in a teleprinter than in the Baudot system.

It is necessary to ensure that the transmitter and the receiver run synchronously in the printing telegraph system. This is accomplished in the Baudot system by sending out a correcting pulse at each revolution of the distributor. In the teleprinter system, the start pulse ensures that the transmitter and the receiver mechanisms start rotating simultaneously; the stop ensures declutching.

Sound transmission, especially speech transmission, to a distance is accomplished in telephony by electrical means. The transmitter converts the sound vibrations into electrical vibrations and the receiver converts the electrical vibrations to the original sound vibrations. The transmitting equipment consists of a carbon button microphone connected to a battery. The sound waves impinging on the sensitive diaphragm of the microphone set up vibrations which alter the resistance of the transmitter and modify the current. The modified current is transmitted

over wire circuits to the distant receiver which converts the varying electric currents into the original sound.

The telephone exchange is a central office where connections are made for local or trunk calls. Two systems of exchanges operate in India, namely the Central Battery Manual system and the Strowger Automatic system.

In the Central Battery Manual system, the connection and disconnection are effected by an operator. When the subscriber lifts his receiver to originate a call, a signal is received by the operator; when he puts the receiver back, the operator receives a signal to indicate that the call has been terminated. The biggest manual exchange now operating in this country is in Calcutta. This is to be shortly replaced by the automatic system, in which connections and disconnections between subscribers are effected by linking switches which operate under the control of electrical pulses sent out from a dial fitted to the subscriber's telephone.

The utility of the telephone system is greatly



P. & T. Workshops, Alipore

FIG. 65—ASSEMBLY OF MANUAL OPERATED SWITCHBOARDS



P. & T. Workshops, Alipore

FIG. 66—ASSEMBLY AND ADJUSTMENT OF HIGH SPEED TELEGRAPH

enhanced by the trunk network. Multi-channel carrier equipments have been installed between cities to negotiate with the large volume of trunk traffic. A three channel telephone carrier enables four telephone conversations to take place simultaneously. A large number of three channel carriers have been installed in India. Recently a twelve channel carrier system, which provides twelve additional channels in addition to the one provided by the wires, has started working between Calcutta and Patna.

The principal consumer of telegraph and telephone equipment in India is the Posts and Telegraphs (P. & T.) Department. The railways, mercantile firms, and Government offices have branch exchanges for intercommunication between different departments. The P. & T. Department meets the needs for all equipment.

The Ministry of Communications operates four factories for the manufacture of telephone, telegraph, and line equipment. The factories are located at Alipore, Jubbulpore, Bombay, and Bangalore.

The Alipore workshop was started in 1860 as a telecommunication maintenance and repair shop.

Manufacture of minor components required for the Baudot telegraph and line stores was initiated in 1913. Production was stepped up under the stimulus of World War I and at the close of the war all components for Baudot and Morse instruments were being produced in the workshop. The manufacture of telegraph instruments, telephones, and switchboards was taken up in the late thirties.

The Jubbulpore workshop was established in 1942 when the Government of India decided to shift the Line Construction Stores section of the Alipore workshop to Jubbulpore. An instruments branch was started in 1945 and the manufacture of components for manual telephones and telegraphs was taken up in the workshop.

The Government of India bought over the telephone workshop from the *Bombay Telephone Company* in 1943. Switchboards and components are produced in this workshop.

The three Government workshops at Alipore, Jubbulpore, and Bombay manufacture nearly all the components and instruments required for telegraphs, manual telephones, and switchboards. They manufacture also line stores, i.e. hardware



ASSEMBLING AND TESTING OF AUTOMATIC TELEPHONES

P. & T. Workshops, Alipore

for telegraph and telephone lines, and undertake repairs of instruments and equipment.

The *Indian Telephone Industries* was established at Dhuravaninagar near Bangalore in July 1948 for the manufacture of automatic and carrier equipment. An agreement was entered into with the *Automatic Telephone & Electric Company* (A.T.E.C.), Liverpool, according to which the English company was to provide the 'know-how' and assist in the manufacture of telecommunication equipment according to a schedule agreed upon. In return, the Government agreed to buy their requirements of telecommunication equipment from the English company through the *Indian Telephone Industries* till such equipment was produced in the country. The schedule covers telephones and automatic exchange, transmission and other equipment. The *Indian Telephone Industries* was converted to a private joint-stock company in February 1950, the Government of India, the Mysore Government, and the A.T.E.C. taking 83, 14, and 3% of the shares respectively. The capital invested by the Government of India up to March 31, 1951 was Rs. 99,78,000.

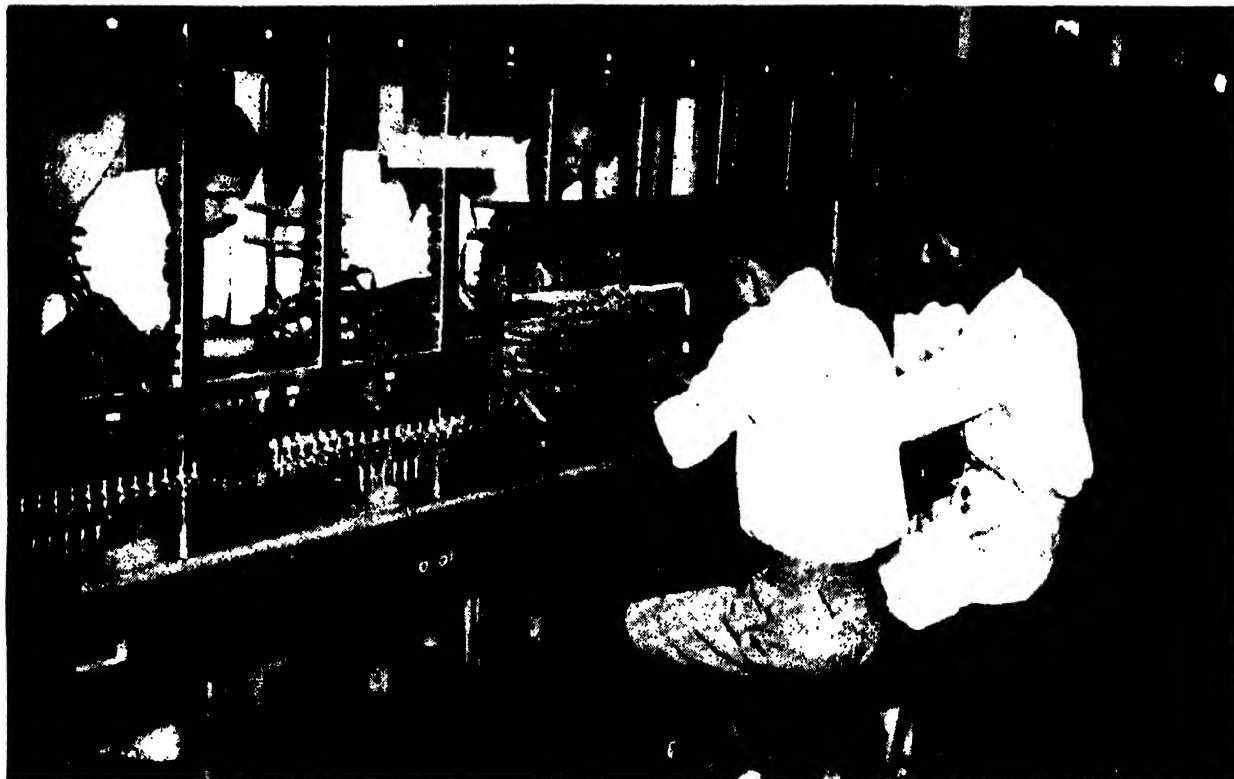
The assembling of telephones from imported parts was started in the factory of the *Indian Telephone Industries Ltd.* at the end of 1948 and the first telephone came off the line on January 26, 1949. Simultaneously arrangements were made for the manufacture of telephone parts and in 1951 telephones were being produced from locally manufactured parts. About 90% of the components required are now being produced in the factory. The original production target was 25,000 telephone instruments and automatic telephone exchange equipment for 30,000 lines per year. The production of telephones was gradually stepped up and in 1952 the target was fixed at 40,000. The target was further increased to 50,000 in 1953.

The factory is equipped with about 700 automatic machine tools of various types, such as autos, capstans, millers, drillers, grinders, and presses; the number is expected to be increased shortly to 1,000. Two precision jig borers, with an accuracy of 0.001 mm. have been installed. There are 12 furnaces comprising salt bath, electric muffle, and forced air circulation furnaces for heat-treatment work, and sections for plating with copper, nickel, zinc, chromium and cadmium,



FIG. 67—CORD SHOP : FINAL TWISTING SECTION

P. & T. Telephone Works, Bombay



P. & T. Telephone Works, Bombay

FIG. 68—SWITCHBOARD WIRING SHOP : C. B. MULTIPLE BOARDS

spray painting, and coil impregnation. The metallurgical laboratory attached to the factory is well equipped for testing work.

Most of the manufacturing processes are automatic and the production is on a mass scale. Iron parts are 'bonderised' (anti-rust treatment) and painted. Other metallic parts are electro-plated and finished.

A few private concerns also are engaged in the manufacture of telegraph and telephone equipment. In 1943-44, about 91 concerns supplied line stores valued at c. 8 lakhs of rupees to the P. & T. Dept. The *Indian Electric Works Ltd.*, Calcutta manufactures magneto telephones, extension switches and bells for magneto telephones, intercommunication telephone sets, magneto switchboards, telegraph sounders (Dubern, Relaying, Poney), sounder screens, morse keys, telephone plugs, and switchboard relays.

Raw materials

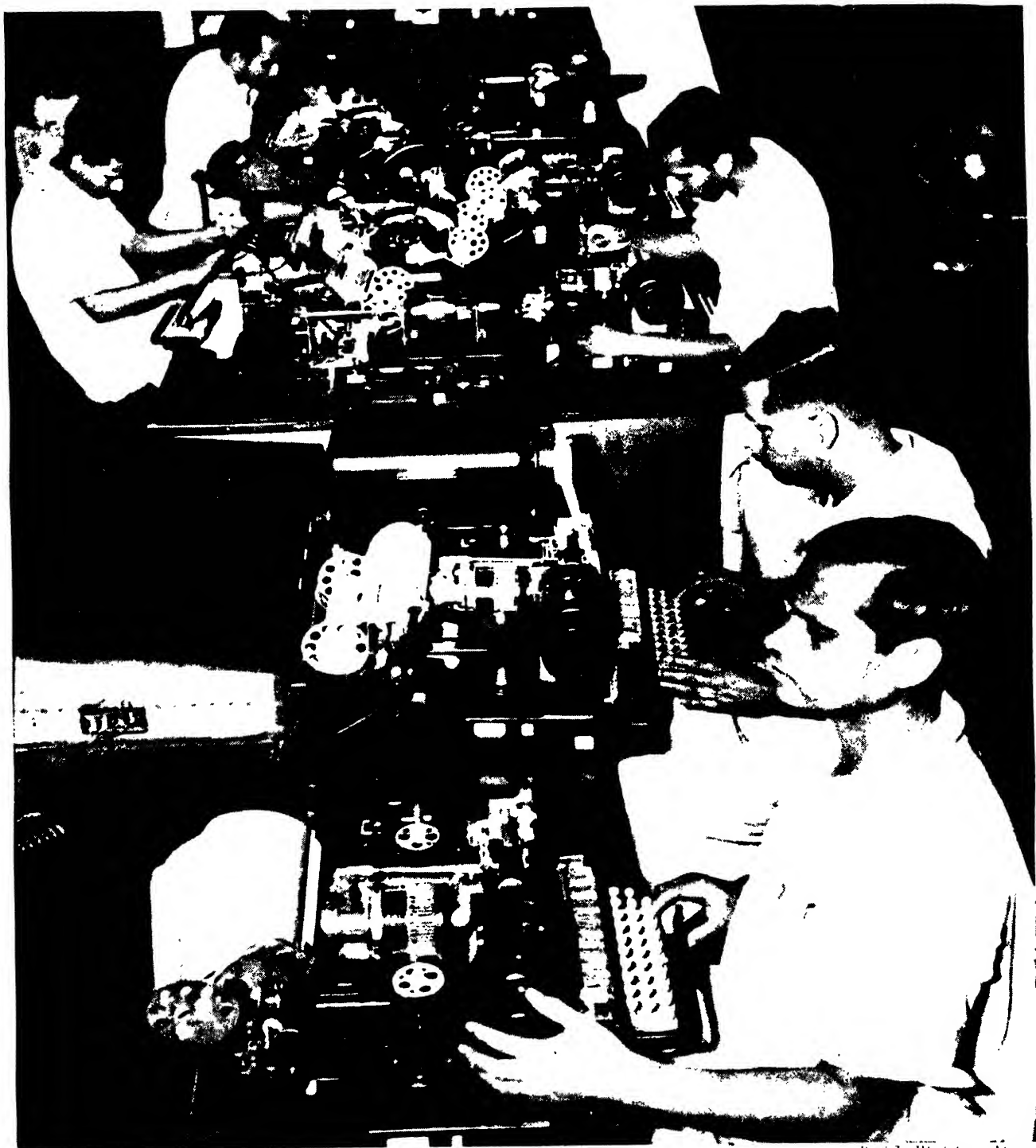
The bulk of raw materials required for the manufacture of telegraph and telephone equipment is available in the country. Materials such as bakelite moulding powder, soft iron, silver, nickel, Monel sheets, zinc, ebonite sheets, solder resin core, empire cloth, winding wire (bare, enamelled,

SSC, and DSC), platinum and silver wire for contacts, switchboard cables, switchboard plugs, lamps and caps for switchboards, H.M.T. hand sets, dials, carbon arrestors, condensers, insets (receivers and transmitters), rubber feet, and Burma teak, are imported.

Manufacture

The production of telegraph and telephone stores and equipment may be grouped under line stores and instruments. The former includes: tapered steel tubes for telegraphs and telephone lines, telegraph and telephone stalks, channel iron brackets, U-backs, straining screws, ties, struts and couplings, bracket attachments (single and double), binding tools, stay rods, braces, wire reels, bolts, nuts, sockets, anchors, sole plates, saddles, caps, pulley blocks, sleeve twisters, and McIntyre sleeves.

Instruments and components produced in the 3 workshops at Alipore, Jubbulpore, and Bombay include trunk board T-32 pattern, C.B. multiple and non-multiple private branch exchange switchboards, public call office equipment, charging boards, phonogram equipment, V.F. repeater racks, balancing boxes for telegraphs; electrical



P. & T. Workshops, Alipore

ASSEMBLING AND TESTING OF TELEPRINTERS

measuring instruments (ammeter, voltmeter, galvanometer, wheatstone bridge, etc.), G.P.O. relays, sounders, cross-talk meters with tone box; intercommunication extension switch, portable terminal telephone sets, telephone plug and sockets (three point and four point), operators' head gear sets, plugs (single pin 4 way and 4 pin for operators' sets), bells of sorts, ringing convertor, alarm fuses, electric clocks, tag blocks, arrestors and heat coil strips, fuse mounting strips, generator boxes, protected cable terminals (indoor and outdoor), telephone switch, subscribers' protector devices, telephone testing units, trunk line commutators, heat coils (earthing and breaking type), magneto switchboards, small P.B.X. boards (3 plus 9 lines and 1 plus 3 lines), P.B.X. floor pattern 20 to 100 extensions, trunk exchange equipment, jack strips, keys, S. & H. relays, B.P.O. relays, relay plates, break jacks, lamp jacks, cable runways, and iron framework for all switchboards.

Automatic exchange—The manufacture of the following items has been taken up in the workshop of the *Indian Telephone Industries Ltd.*: main distribution frames (M.D.F.); tie bars; cable runways; single line protectors for

subscribers' offices; fuse strips P.O. 4028 for M.D.F.; arrestor strips P.O. 40B for M.D.F.; and tag blocks. The manufacture of other items, such as unselector racks, group selector racks, final selector racks, two motion switches for group and final selector racks, B.P.O. 600 type relays for line circuit, and B.P.O. 3000 type relays for group and final selectors, are to be taken up shortly. About 20,000 switches are proposed to be made from imported mechanisms and banks. B.P.O. 600 type relays used in line circuits and B.P.O. 3,000 type relays used on group and final selectors will be assembled partly from imported parts and partly from locally produced parts. Racks will be completely equipped and wired.

The *Indian Telephone Industries Ltd.* intend to manufacture railway traffic control equipment, army telephone and transmission equipment. Portable train control equipment has been produced and supplied to railways. Field telephones and portable magneto telephones are being developed in collaboration with the Defence Department. Development is also proceeding on transmission equipment, such as single channel carrier, voice frequency repeater, ranging repeater, and transmission measuring sets.



Indian Telephone Industries Ltd., Bangalore

FIG. 69—ASSEMBLY OF AUTOMATIC TELEPHONE EQUIPMENT



Indian Telephone Industries Ltd., Bangalore

FIG. 70—TELEPHONE ASSEMBLY SECTION

Production and trade

Tables 86, 87, and 88 give the production in the

TABLE 86—PRODUCTION OF TELEPHONE AND TELEGRAPH EQUIPMENT IN ALIPORE WORKSHOP
(in numbers)

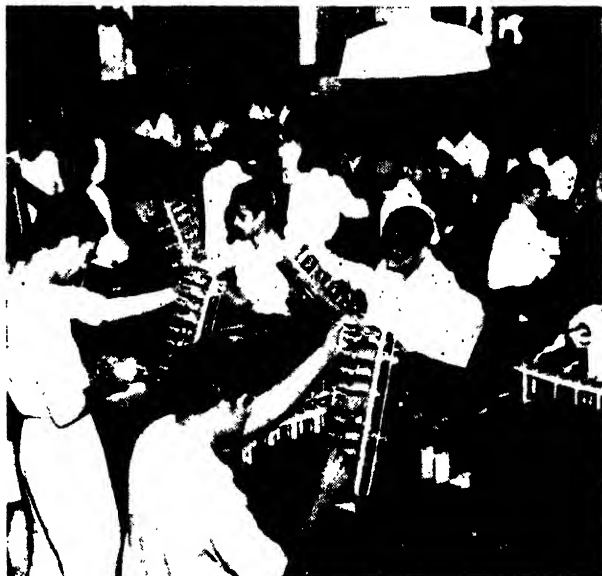
| | 1948-49 | 1949-50 | 1950-51 |
|-------------------------------------|---------|---------|---------|
| Sockets | 28,323 | 30,603 | 49,140 |
| Anchors | 110,009 | 49,247 | 32,942 |
| Brackets, channel iron | 23,536 | 82,812 | 84,470 |
| Stalks | 340,505 | 350,021 | 294,303 |
| U-backs | 35,055 | 4,269 | 79,512 |
| Straining screws (new pattern 1/2") | 38,725 | 19,725 | 45,000 |
| Desk sets | 3,300 | 6,053 | 15,048 |
| Dubern sounder | 164 | 128 | 365 |
| Switchboards (lines) | 169 | 52 | 48 |
| Heat coils | 21,280 | 87,740 | 101,214 |
| Arrestors | 213 | 259 | 65 |
| Protected cable terminals, 32 type | 250 | 500 | 325 |
| Alarm fuses | 2,700 | 4,280 | 4,634 |

TABLE 87—PRODUCTION OF TELEPHONE AND TELEGRAPH EQUIPMENT IN JUBBULPORE WORKSHOP
(in numbers)

| | 1948-49 | 1949-50 | 1950-51 |
|------------------------|---------|---------|---------|
| Brackets, channel iron | 143,785 | 8,800 | 12,000 |
| Stalks | 158,300 | 235,850 | 283,700 |
| U-backs | 77,400 | 79,815 | 60,680 |
| Heat coils | 1,952 | 9,523 | 30,052 |
| Tubes | 126,374 | 107,472 | 86,661 |
| H.M.T. sets | 4,375 | 3,234 | 2,751 |
| Ties | 22,120 | 45,413 | 13,500 |
| McIntyre sleeves | 81,500 | 189,465 | 34,000 |

three P. & T. workshops at Calcutta, Jubbulpore, and Bombay during the years 1948/49-1950/51.

The Indian Telephone Industries Ltd. produced 48,328 telephone instruments since it started functioning up to the end of April 1952. Table 89 gives the production of telecommunication equipment in 1951.



P. & T. Telephone Works, Bombay

FIG. 71—RELAY ASSEMBLY SECTION

TABLE 88—PRODUCTION OF TELEPHONE AND TELEGRAPH EQUIPMENT IN BOMBAY WORKSHOP
(in numbers)

| | 1948-49 | 1949-50 | 1950-51 |
|--|---------|---------|---------|
| Switchboards (lines) | 7,653 | 14,254 | 14,440 |
| Cordage of switchboards and instruments, yd. | 132,232 | 408,875 | 497,741 |
| 4-Bar generators | 422 | 1,783 | 267 |
| Battery boxes | 929 | 448 | |
| Private branch exchange distribution boxes | 79 | 79 | |
| Junction boxes | 242 | 221 | 1,374 |
| Relays | 430 | 830 | 1,823 |

TABLE 89—PRODUCTION OF TELECOMMUNICATION EQUIPMENT IN 1951*
(in numbers)

| | |
|-------------------------|----------------------------|
| Telephones | 16,850 |
| M.D.F. } | for 30,000 lines equipment |
| I.D.F. } | |
| Tie bars } | (a) |
| Cable runways } | |
| Fuse strips 4028 | 40 |
| Arrestor strips 40B | 800 |
| Single line protectors | 700 |
| Unselector racks | 18† |
| Group selector racks | 23† |
| Final selector racks | 18† |
| B.P.O. 600 type relays | 11,300 |
| B.P.O. 3000 type relays | 2,900 |

* Information from the *Indian Telephone Industries Ltd.*, Bangalore

(a) Small quantity (quantity not known)

† Iron work completed and wiring started

TABLE 90—PRODUCTION PROGRAMME (ANNUAL)*

| | Qty (no.) |
|-----------------------------------|------------------|
| Telephones : | |
| Central battery | 18,000 |
| Auto | 30,000 |
| Magneto | 2,000 |
| Dials | 40,000 (a) |
| Automatic exchange equipment (b): | |
| Unselector racks | 100 |
| Group selector racks | 100 |
| Final selector racks | 100 |
| M.D.F. } | for 30,000 lines |
| I.D.F. } | |
| Fuse strips | 2,500 |
| Arrestor strips | 2,000 |
| Single line protectors | 10,000 (c) |
| Relays 600 type | 60,000 |
| Relays 3000 type | 100,000 |
| Unselector switches | 30,000 |
| Two motion switches | 11,500 |
| Condensers | 130,000 |

* Information from the *Indian Telephone Industries Ltd.*, Bangalore

(a) In addition to those required for auto telephones

(b) For 30,000 lines of automatic exchange equipment

(c) Number to be reviewed in consultation with P. & T. Dept.

TABLE 91—IMPORTS OF TELEGRAPH AND TELEPHONE INSTRUMENTS AND APPARATUS

(Val. in lakh Rs.)

| | From | | |
|-----------------------|--------|-----------------|--------|
| | U.K. | Other countries | Total |
| 1934/35-1938/39 (av.) | 14.75 | 4.60 | 19.35 |
| 1939/40-1943/44 (av.) | 11.36 | 1.41 | 12.77 |
| 1944-45 | 20.52 | 2.87 | 23.39 |
| 1945-46 | 39.23 | 1.52 | 40.75 |
| 1946-47 | 38.06 | 0.59 | 38.65 |
| 1947-48 | 27.08 | 3.25 | 30.33 |
| 1948-49 | 33.26 | 5.66 | 38.92 |
| 1949-50 | 47.67 | 3.45 | 51.12 |
| 1950-51 | 106.50 | 3.00 | 109.50 |
| 1951-52 | 23.86 | 3.20 | 27.06 |
| 1952-53 | 29.01 | 9.50 | 38.51 |

Table 90 gives the quantity of telephone and other equipment for automatic exchanges proposed to be manufactured annually for the next few years.

Table 91 gives the imports of telegraph and telephone instruments and apparatus into India. Table 92 gives the imports of telegraph and telephone apparatus from U.K. into India during the years 1947 and 1948.

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TABLE 92—IMPORTS OF TELEGRAPH AND TELEPHONE APPARATUS FROM U.K.*
(Val. in £)

| | 1947 | 1948 | 1949 | 1950 |
|---|-------------------|--------------------|--------------------|-------------------|
| Telegraph and telephone equipment : | | | | |
| Complete installation | 125,833 | 6,495 | 371,820 | 224,194 |
| Telephone instruments, complete, separately consigned | 19,762 (3,987) | 86,823 (19,310) | 75,979 (16,016) | 50,538 (9,237) |
| Parts | 173,899 | 129,979 | 407,137 | 456,900 |
| Testing equipment | 2,028 | 521 | 1,297 | 8,414 |
| Line apparatus for long distance communication and speech input equipment | 16,355 | 43,876 | 14,211 | 39,641 |
| Signalling apparatus | 21,098 | 22,470 | 35,493 | 60,928 |

Figures within brackets indicate numbers

* Tr. U.K.

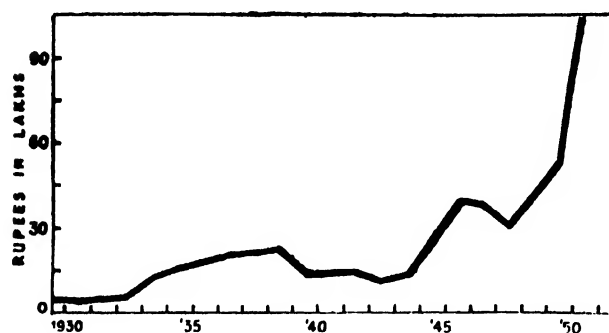


FIG. 72—IMPORTS OF TELEGRAPH AND TELEPHONE INSTRUMENTS AND APPARATUS

Imports of telegraph and telephone instruments, apparatus and appliances, condensers, bell apparatus and switchboards designed for use in circuits of less than 10 amp. and at a pressure not exceeding 250 volts are subject to a revenue duty of $31\frac{1}{2}\%$ *ad valorem* with a preferential rate of $10\frac{1}{2}\%$ *ad valorem* in the case of articles from Burma. Such instruments imported by or under the orders of railway administration are subject to a revenue duty of $19\frac{17}{32}\%$ *ad valorem* with the preference of free import for articles from Burma.

Transformers

The transformer provides a simple, efficient, and stationary device for changing electrical energy from a given pressure to a higher or lower pressure. It operates only with alternating currents and is an extremely important link in the scheme of power transmission and distribution.

The loss of energy in a conductor varies with the square of the current and this factor limits the amount of power that can be transmitted to points situated at a distance from the generator. There is a loss of voltage also during transmission. The power conveyed over a transmission line is

proportional to the voltage and current, and if the voltage can be increased, the current can be decreased and both energy loss and voltage drop can be minimized. The importance of a device which permits voltage changes to be effected at generation and distribution points will therefore be readily appreciated. Indeed notable developments in commercial power transmission have taken place only after the invention of the transformer.

The transformer consists of two coils of wire insulated from each other wound on a laminated steel core. When an alternating current flows through one of the coils, a pulsating magnetic flux is produced in the core. A part of the flux is linked by the windings of the second coil as a result of which an opposing voltage is induced in the second coil, depending upon the rate of change of the total flux linked. The winding on which the voltage is impressed is the 'primary' and the other, the 'secondary'. The voltage induced in the secondary coil is almost in direct ratio to the number of turns in the two windings. With 1,000 turns in the primary connected to 2,300 volts, a voltage of 230 volts will be induced in the secondary if it contains 100 turns and 11,500 volts if it contains 5,000 turns.

Different types of transformers have been designed to meet varying applications. Based upon the type of construction, transformers are classified as core type and shell type. In the core type, the primary and secondary windings encircle the core or the magnetic circuit. In the shell type, the magnetic circuit surrounds the windings. The core type has a relatively long magnetic circuit and a short electric circuit. In the shell type, the magnetic circuit is relatively short while the electric circuit is long. Both types can be used for large capacity and high voltage work. The core type is more suitable for high voltages because the coils can be more easily wound and insulated than in the shell type of

construction. The coils in core type transformers radiate heat more rapidly as they are located on the outside. Also, the windings are easy to remove for repair and replacement.

The shell type is well suited for moderate voltages and heavy currents. The coils being located at the centre are mechanically well protected. However, the coils are not accessible for inspection and repair without dismantling the core but this is not considered serious in modern transformers which are of high reliability and seldom need repairing. The shell type construction permits reduction in magnetic end-leakage.

Three-phase core type transformers have cores with three legs, each surrounded by primary and secondary windings. For reducing the height of the core, the iron circuit is modified by having two extra legs without windings and the yoke of the iron circuit is reduced in size.

In the shell type, which is generally used in single-phase transformers, both the primary and secondary windings are on the centre leg; a shell type three-phase transformer is an assembly of three single-phase transformer units. The coils may be wound on circular forms or rectangular forms.

Transformers are also classified according to the method of cooling adopted. A transformer in service develops heat due to 'iron and copper losses'. Active power is lost as heat in the resistances of the primary and secondary windings—'copper loss' and in the magnetic circuit under the influence of the fluctuating magnetic field—'iron loss' or 'core loss.' The iron loss is due to eddy currents and hysteresis in the magnetic circuit. According to the method of cooling employed transformers may be oil-immersed or dry. Oil immersion is adopted for high voltage or high power transformers—both for cooling and improved insulation. For miniature transformers cooling by natural circulation of air is adopted for convenience. Considerations of fire risk sometimes lead to the use of dry transformers even in large sizes, cooled by air. In such cases air is blown by fans through ducts in the cores and windings. Most transformers, however, are cooled by oil immersion. The coils and cores are mounted in a tank filled with oil; the oil serves to dissipate the heat produced and in addition acts as an insulating medium. For additional cooling, water may be circulated in sealed tubes inserted in the insulating oil or jets of air blown on radiating pipes provided on the tanks.

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The first transformer factory to be established in India was the *Government Electric Factory*, Bangalore (1936-37). The total power capacity of transformers produced in the factory was 6,000 kVA per year before World War II. Due to import

restrictions during the war years and increased demand for transformers by industry and defence establishments, the need for stepping up indigenous production became pressing. Three factories, namely *Crompton Parkinson (Works) Ltd.*, Bombay, *Associated Electric Industries Mfg. Co.*, Calcutta, and *Kaycee Industries Ltd.*, Lahore were set up through government assistance. Subsequent to 1947 the *Kaycee Industries Ltd.* acquired the workshops of *Mallik Electric Works*, Bombay and are manufacturing transformers in their factory, *Radio Lamp Works Ltd.*, Bombay. Three new factories, the *National Electrical Industries Ltd.*, Bombay, *Electric Construction & Equipment Co. Ltd.*, Calcutta, and *Radio and Electricals Ltd.*, Madras, have recently gone into production.

In addition to the above firms, two firms—*Kirloskar Electric Co. Ltd.*, Bangalore and *General Electric Co. of India Ltd.*, Calcutta, propose to set up plants for the manufacture of transformers. The former concern will produce in technical collaboration with *Brush Electrical Engineering Co. Ltd.*, Loughborough, 50-500 kVA transformers with an initial production of 50,000 kVA per annum. The *General Electric Co. of India Ltd.* will manufacture transformers up to 2,500 kVA and 11 kV and the annual rated capacity of the plant is estimated to be 15,000 kVA during the period of the first Five-Year Plan. The *Radio and Electricals Ltd.*, Madras and the *Government Electric Factory*, Bangalore, have plans to extend their plant capacities.

Only core type transformers are manufactured in India. The total annual power capacity of transformers produced in India rose from 6,000 kVA during pre-war years to 78,000-84,000 kVA in 1946, a large number of transformers produced having ratings up to 250 kVA and 11 kV on the H.T. side. The total installed capacity of the 7 manufacturing concerns in 1952 was 370,000 kVA per annum. With the implementation of the development projects, the annual capacity of the transformer industry would amount to c. 485,000 kVA.

Transformers rated 2,500 kVA at 33 kV are being produced in India. The scheme of the *Kirloskar Electric Co. Ltd.*, Bangalore includes the manufacture of transformers up to 5,000 kVA at 33 kV.

Raw materials

The principal raw materials for transformers are silicon steel sheets, copper wires for windings, mild steel plates for tanks, and bushings for insulating and bringing the terminals of windings out of the tank.

The cores are made from laminations of high silicon steel on account of their low hysteresis and eddy current losses. Hysteresis is caused by the periodic reversal of the direction of the magnetic flux in the core and eddy current loss is caused by

local circulation currents in the iron as a result of voltages induced by the alternating flux. Silicon steel also shows superior permeability in comparison to the common forms of iron at moderate flux densities. Its non-aging quality also renders the use of high silicon steel for transformer core an advantage; unlike other forms of iron whose core losses increase with use, the core loss in silicon steel is unaffected by age. The higher the silicon content, the better the steel with regard to magnetic properties, but the hardness increases and the steel becomes increasingly brittle so that rolling, punching, shearing, bending, etc. offer difficulties. The saturation induction for silicon steel decreases with rise in silicon content. Transformers are generally designed to operate with a flux density of approximately 13,500 lines per sq. cm. and acceptable iron losses are obtained with this density although the tendency is for iron losses to be reduced still further by the use of steels with lower losses.

Recent advances in cold rolling technique have rendered possible further reduction in iron losses. By orientating the grain along the direction of rolling the specific loss in cold reduced sheets has been lowered to a level previously considered quite unattainable by the orthodox hot rolling methods.

The magnetic properties of transformer sheet steels depend on the direction of the grain produced by rolling; hence as far as possible sheets are sheared along the grain, which is the direction in which the material has high permeability (Say, 33).

High silicon steel with 3.5-4% silicon are used for transformers. The steel is rolled into sheets of thickness ranging from 0.007 to 0.014 in.

B.S.S. No. 601—1935 lays down specifications for transformer steel sheets. Specifications are given for 3 grades designated A, B, and C. Table 93 gives the maximum iron losses for the 3 grades at flux densities (B max.) of 10,000 and 13,000 lines per sq. cm. (gauss) and at a frequency of 50 cycles. The minimum permeability of the material should not be less than that derived from the values of magnetizing force (H) and flux density (B) given in Table 94.

Indian requirements of high silicon steel are obtained from *Tata Iron & Steel Co. Ltd.*, Jamshedpur. The sheets are distributed by *Sankey Electrical Stampings Ltd.*, Bombay and Calcutta.

TABLE 93—MAXIMUM IRON LOSS FOR SILICON SHEETS

| | At flux density of 10,000 lines/sq. cm. (watts/lb.) | At flux density of 13,000 lines/sq. cm. (watts/lb.) |
|---|---|---|
| A | 0.52 | 0.93 |
| B | 0.57 | 1.00 |
| C | 0.64 | 1.11 |

TABLE 94—MINIMUM PERMEABILITY FOR SILICON SHEETS

| Magnetizing force (H) c.g.s. units/cm. (Oersted) | Flux density (max.) (Gauss) |
|---|--------------------------------|
| 3.0 | 10,000 |
| 5.0 | 12,000 |
| 8.5 | 13,000 |
| 21.0 | 14,000 |
| 46.0 | 15,000 |
| 94.0 | 16,000 |

TABLE 95—TATA HIGH SILICON STEEL : TOTAL IRON LOSS AT 50 CYCLES

| Thickness (BG) | At flux density of 10,000 lines/sq. cm. (watts/lb.) | At flux density of 13,000 lines/sq. cm. (watts/lb.) |
|-------------------|---|---|
| 29 | 0.63 | 1.07 |
| 28 | 0.67 | 1.14 |
| 27 | 0.70 | 1.19 |
| 26 | 0.74 | 1.26 |
| 25 | 0.77 | 1.31 |
| 24 | 0.82 | 1.39 |
| 22 | 0.90 | 1.53 |

They are tested and punched according to the needs of transformer manufacturers. The gauge commonly employed in transformer manufacture is 29 (BG.) (0.014 in.).

The composition of high silicon stalloy steel produced by *Tata Iron & Steel Co. Ltd.*, is as follows : C, 0.08; Mn, 0.12; Si, 3.9-4.3; S, 0.012; and P, 0.010%. The total iron loss in watts per lb. at 50 cycles is given in Table 95.

Windings—Insulated copper wires are used for transformer windings. For smaller currents, round copper wire insulated with cotton, enamel, paper, or a combination of these materials, is used. Coils for carrying heavy currents are made from conductors of large sections.

L. T. coils are made from double cotton covered round copper wires or flat strips. Depending on the voltage and current, H.T. coils are wound with either round wires or rectangular strips insulated by cotton or paper covering. Large conductor sections are made of several rectangular strips insulated from each other.

Oil—Transformer oil should conform to rigid specifications. It should not deteriorate due to oxidation which leads to the formation of oil-soluble acid products and acidic and neutral resinous compounds insoluble in oil. The insoluble products are deposited as sludge on windings and cores, thereby impairing cooling and lowering the dielectric strength of the insulation. The following characteristics of transformer oils are specified in B.S.S. 148—1951 :

(1) The oil should be absolutely clear; (2) the acidity neutralization value should not exceed

TABLE 96—REQUIREMENTS OF RAW MATERIALS*
(Total capacity of transformers, 270,000 kVA)

| | Val. (thousand Rs.) |
|--|------------------------|
| Indigenous : | |
| Electrical steel sheets or laminations† | 1,450 |
| Insulated copper wires and strips | 1,030 (110 tons) |
| Electrolytic copper bars and wires | 36 |
| M.S. plates, sheets, strips, rods, bars, etc. | 296 |
| Iron castings | 27 |
| Brass castings | 155 |
| Aluminium castings | 35 |
| Non-ferrous metals | 24 |
| Insulating varnish | 15 |
| Bushings | 31 |
| M.S. bolts, nuts, screws | 50 |
| Special components | 6 |
| Imported : | |
| High silicon, low watt loss, electrical steel sheets | 800 |
| Enamelled copper wires | 351 (50 tons) |
| Other insulated copper wires and strips | 400 (55 tons) |
| Cables and flexibles | 1 |
| Electrolytic copper bars and wires | 8 |
| M.S. plates, sheets, strips, rods, bars, etc. | 18 |
| Wrought iron pipes and tubes | 300 |
| Non-ferrous metals | 24 |
| Empire cloth, steerings, tubes, etc. | 17 |
| Bakelite board and tubes | 14 |
| Leatheroid | 14 |
| Insulating varnish | 72 |
| Bushings | 162 |
| M.S. bolts, nuts, screws | 120 |
| Langite and bonded cork sheets | 22 |
| Transformer oil | 513 (1.2 lakh gal.) |
| Special components | 652 |

* Information from the Planning Commission

† Total quantity required, imported as well as indigenous, is estimated at 1,500 tons

Imported raw materials account for about 53% of the total

0.05 mg. KOH/g.; (3) the oil as sampled from a new drum should have a withstand value of 40 kV for one minute when tested across a sphere gap consisting of 13 mm. diam. electrodes 4 mm. apart; this test must be successful for two samples out of three; (4) the flash point determined according to Pensky-Martens method should not be lower than 146°; (5) viscosity at 21° should not exceed 37 centistokes. The transformer temperature should constantly be under observation. The oil temperature should not exceed 90° at which point the temperature of the hottest part of the windings is estimated to be 105°, but their av. temperature should not exceed 95° with class

A insulating materials as defined in B.S.S. 171-1936.

Table 96 gives the requirements of raw materials for the production of transformers with a total power capacity of 270,000 kVA.

Manufacture

For making core type transformers, punchings for the bottom yoke and the legs are assembled and the yoke bolted to end frames. The core is put upright, coils previously made are lowered on to it, and the top yoke fixed.

For core construction the laminations are insulated on both sides by varnish. Burrs on edges of sheets are smoothened.

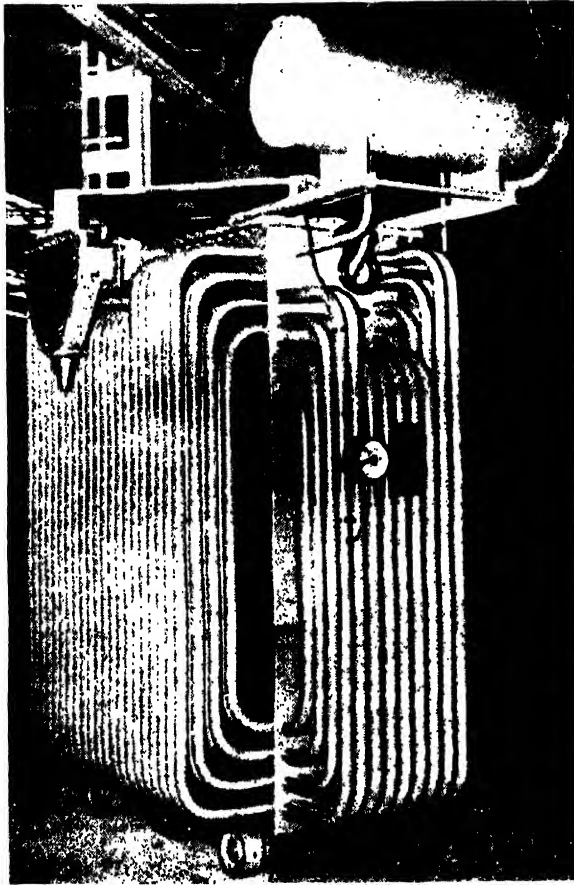
Punchings for core type transformers are usually of rectangular cross section. Limbs and yokes are separately assembled. Individual laminations are stacked one upon another, each layer forming a closed magnetic path. Alternate layers are staggered so that all joints do not come in the same place. Air gaps are thereby avoided. Limbs are generally rectangular; in large sizes, however, a cruciform section is employed to reduce the length of the mean turn and the consequent copper loss.

Cores of small transformers are built up of laminations of E or L shape. Two punchings are butted together to form a layer and the joint is overlapped by punchings in adjacent layers.

Laminations in limbs are clamped together under heavy pressure by bolts or rivets which are insulated from the plates as well as from the laminations by washers and bushes. Yokes are also similarly assembled but laminations are clamped by bolting between channel iron sections which also hold the yokes in magnetic contact with the limbs. Laminations of limbs are overlapped with those of the yoke to give an air-free path for the flux. The completed core is a solid rigid structure with low reactance path for the magnetic flux and high resistivity for preventing eddy currents.

Core sizes for transformers have been standardized.

Coils are generally former wound. They are circular or rectangular. In most cases the limbs are of cruciform section. Circular coils are easier to make and resist mechanical forces due to short-circuiting or heavy overloads. The ratio of the number of turns in the primary to the number of turns in the secondary windings is governed by the voltage ratio; the actual number depends on the design and on the inter-connection of phases in poly-phase transformers. The induced e.m.f. in the turns of either winding interlinking with the core flux should be approximately equal to the rated voltage of the winding and the exciting current in either winding producing this flux at the rated voltage must not exceed the usual proportion of full load current. The insulation



Crompton Parkinson (Works) Ltd., Bombay

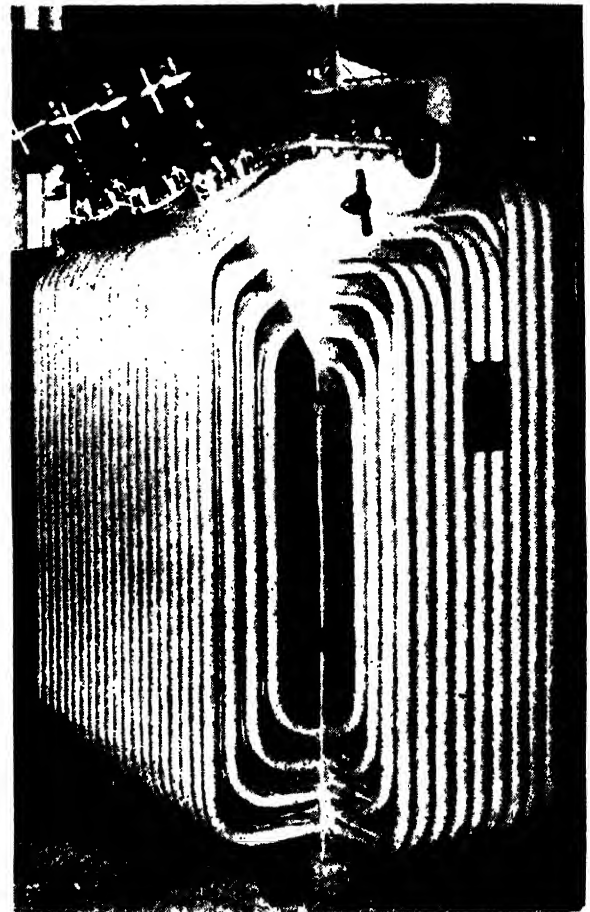
FIG. 73—A 1,500 KVA TRANSFORMER : L. V. SIDE

between turns of a winding, between two windings, and between the core and the windings should be effective (Stubbings, 119).

Wire of circular cross section is used for coils in transformers intended to carry small currents. The coil is wound in a number of layers, each layer with several turns. Insulation between turns is provided by layers of paper inserted to add also mechanical strength to the coil. The complete winding consists of a number of such coils assembled together and spaced from each other by insulation blocks. For heavy currents the conductor is composed of wires of rectangular cross section arranged side by side. The coil is wound in one or more layers and at the end of each layer is placed an edge strip of insulating material shaped at one end to take the spiral form of the winding and make the ends level. At the ends of windings adjacent to the line, the insulation is reinforced to withstand the effect of surges.

Low tension coils are built of multi-layers, usually two, each consisting of a number of turns of wire. The layers are spaced by strips of insulation. The completed L.T. coil is one continuous wire built in a number of layers. Coils for larger sizes (> 100 kVA) may be made in one layer but two layers are preferred from design considerations.

H.T. coils may be wound in single or multi-layers. Transformers for less than 1,000 volts are built with single spiral H.T. coil running from one end of the limb to the other; for transformers above 1,000 volts disc type or cross-over coils, consisting of a number of coils insulated from each other and connected in series to form a complete winding of the required number of turns, are used. This type of construction ensures effective insulation. The coils are series and parallel connected for obtaining different voltages.



Crompton Parkinson (Works) Ltd., Bombay

FIG. 74—A 1,250 KVA TRANSFORMER : H. V. SIDE



Crompton Parkinson (Works) Ltd., Bombay

FIG. 75—GENERAL VIEW OF 15 TON TRANSFORMER BAY

H.T. and L.T. coils are arranged concentrically on the limbs, i.e. the high tension winding is put over the low tension winding, the latter being next to the core. The leakage flux is small on account of the high reactance of the path of the leakage flux which lies in the long annular space between the two windings. Individual windings are dried under vacuum in an oven at 90° and immersed in a special insulating compound under pressure. Coils are later baked at 90° .

Bakelised paper cylinders or Fuller board cylinders are used as insulation between low and high tension windings to prevent a 'flash over' from the H.T. to the L.T. winding. Composition tubes or layers of Fuller board are used as insulation between the core and the L.T. winding. Flash over from ends of windings to the top and bottom yokes of the core is prevented by the use of spacing blocks of adequate dimensions.

Coils are securely wedged and anchored to prevent movement due to magnetic stresses. The top yoke is fixed to the limbs. The whole core

is securely clamped by bolts to prevent vibration of laminations.

High voltage and low voltage windings are so placed relative to each other that their magnetic centres are nearly coincident. Also the heights of high voltage and low voltage windings are kept equal; this reduces the mechanical stresses under short-circuit conditions to the minimum. The assembled unit of core and windings is dried at 90° in a heated vacuum tank and impregnated under pressure with hot transformer oil of high dielectric strength.

Transformer tanks are made of steel plates with welded seams and are generally rectangular in shape. They are tested to ensure oil-tightness. For small sizes of transformers, the plain sides of tanks provide sufficient radiating surface to dissipate the heat. For larger sizes (> 50 kVA), round tubes are welded into the sides of the tanks to provide additional radiating surface. Tanks may be provided with lifting lugs, plain rollers, and other special fittings.

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The main tank is completely filled with oil; for the expansion of oil due to temperature changes an auxiliary tank mounted at a level higher than the top surface of the tank is provided. The two tanks are connected by a tube of comparatively small diameter, so that the oil in the main tank does not mix freely with that in the auxiliary vessel. The auxiliary tank prevents the ingress of moisture into the transformer and protects the oil in the main tank from deterioration due to oxidation. The connecting tube protrudes a small distance into the auxiliary tank to form a sump. Any moisture which may have collected inside the tank is thereby prevented from entering the transformer. The moist oil can be drawn off through a drain valve at the bottom.

A silica gel breather is sometimes fitted to the auxiliary to prevent ingress of moisture. The silica gel can be used over and over again after regeneration.

The ends of coil windings are connected to copper rods or bars, insulated wholly or in part, and taken to porcelain insulator bushings at the top of the tank.

Types of products—Both indoor and outdoor types of oil-immersed, self-cooled, 3-phase distribution transformers up to 2,500 kVA rating and 33 kV on the high tension side are manufactured in India. The bulk of production has so far been in the form of 3-phase transformers up to 11 kV.

Transformers of 5 to 200 kVA. capacity are made with standard ratings of 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 75, 100, 150, and 200 kVA. Standard ratings for medium power transformers are 250,

300, 400, 500, and 1,000 kVA. B.S.S. 171—1936 specifies standards for voltage values, but these are not always adhered to as different transmission systems have different requirements.

Production and trade

The number of distribution transformers produced in India in pre-war and war years was as follows: pre-war 60 (val., Rs. 60,000); 1942, 200 (val., Rs. 2,00,000); 1943, 600 (val., Rs. 6,00,000); 1944, 1,500 (val., c. Rs. 15,00,000) (Thomas, *Rep. Metall. Engng Industries*, 67).

Table 97 gives the production of power transformers since 1946. Table 98 gives the production of power transformers during 1949, 1950, and 1951 according to kV ranges.

The production of transformers has been steadily increasing since 1947. The actual production has not, however, caught up with the installed capacity due to shortages in material, such as cooling tubes, mild steel plates, insulating materials, winding wires, and bushings.

TABLE 97—PRODUCTION OF POWER AND DISTRIBUTION TRANSFORMERS

| | kVA | Val. (Rs.) |
|------|---------|---------------|
| 1946 | 38,892 | 1,270 |
| 1947 | 32,000 | 1,000 |
| 1948 | 81,973 | 1,130 |
| 1949 | 84,842 | 982 |
| 1950 | 153,181 | 1,277 |
| 1951 | 183,164 | 1,926 |
| 1952 | 214,950 | |

n.a.—not available

TABLE 98—PRODUCTION OF 3-PHASE TRANSFORMERS ACCORDING TO RATINGS

| | 1949 | | 1950 | | 1951 | |
|-------------------|------|--------|-------|---------|-------|---------|
| | no. | kVA | no. | kVA | no. | kVA |
| Up to 3.3 kV | 169 | 15,831 | 268 | 17,301 | 313 | 23,300 |
| 3.3 — 6.6 kV | 117 | 21,271 | 167 | 43,460 | 252 | 53,791 |
| 6.6 — 11 kV | 588 | 38,190 | 793 | 86,035 | 317 | 95,473 |
| 22 kV | | | | | | |
| Up to 25 kVA | | 175 | 10 | 250 | | |
| 25 — 75 kVA | 76 | 4,725 | 20 | 1,185 | 10 | 500 |
| 75 — 250 kVA | 22 | 2,650 | 15 | 1,700 | 20 | 2,350 |
| 250 — 500 kVA | 2 | 1,000 | 1 | 500 | 7 | 2,900 |
| 500 — 1,000 kVA | 1 | 1,000 | 3 | 2,750 | 4 | 3,100 |
| 1,000 — 1,500 kVA | | | | | 1 | 1,250 |
| 33 kV | | | | | | |
| 75 up to 250 kVA | | | | | 2 | 500 |
| Total | 982 | 84,842 | 1,277 | 153,181 | 1,926 | 183,164 |

* The Planning Comm., *Programmes of Industrial Development 1951-56, 1953, 1957*

Imports—Table 99 gives the imports of power transformers into India. Tables 100 and 101 give imports from U.K. and U.S.A. respectively.

The bulk of the imports comes from U.K. The percentage shares of different countries in the imports during the quinquennium ending 1938-39 were: U.K., 68.0; U.S.A., 40.0; and Sweden, 7.3%. During the quinquennium ending 1943-44, U.K. supplied 85.5% of the total imports. Imports of electric transformers into India are subject to a revenue duty of 5½% *ad valorem*.

The Planning Commission has estimated that the

TABLE 101—IMPORTS OF TRANSFORMERS FROM U.S.A.*
(Qty in numbers and val. in \$)

| | Power | | Distribution | |
|------|-------|---------|--------------|--------|
| | Qty | Val. | Qty | Val. |
| 1946 | 9 | 113,827 | 4 | 297 |
| 1947 | 7 | 78,972 | 66 | 7,110 |
| 1948 | 19 | 361,543 | 55 | 19,424 |
| 1949 | 16 | 74,552 | 36 | 54,914 |
| 1950 | 11 | 86,351 | 37 | 60,197 |
| 1951 | 15 | 799,007 | | 4,389 |

* U.S. Exports of Domestic & Foreign Merchandise

TABLE 99—IMPORTS OF POWER TRANSFORMERS

| | No. |
|-----------------------|-------------|
| 1934/35-1938/39 (av.) | 20,68,410 |
| 1939/40-1943/44 (av.) | 20,77,487 |
| 1944-45 | 53,63,894 |
| 1945-46 | 37,84,478 |
| 1946-47 | 42,91,696 |
| 1947-48 | 47,81,499 |
| 1948-49 | 1,09,98,258 |
| 1949-50 | 1,41,37,644 |
| 1950-51 | 1,53,52,896 |
| 1951-52 | 1,44,55,215 |
| 1952-53 | 1,44,24,851 |

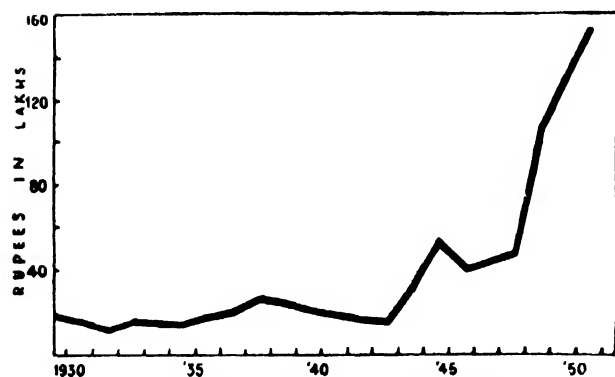


FIG. 76—IMPORTS OF TRANSFORMERS

TABLE 100—IMPORTS OF POWER AND DISTRIBUTION TRANSFORMERS FROM U.K.*

| | Qty (tons) | Val. (£) |
|------|---------------|-------------|
| 1942 | 743 | 109,151 |
| 1943 | 1,059 | 181,777 |
| 1944 | 1,712 | 325,453 |
| 1945 | 1,239 | 223,677 |
| 1946 | 1,845 | 392,100 |
| 1947 | 1,448 | 321,052 |
| 1948 | 2,704 | 647,690 |
| 1949 | 3,492 | 865,142 |
| 1950 | 4,233 | 1,180,875 |

* Tr. U.K.

requirements of power and distribution transformers up to 33 kV would be 2.65 million kVA during the quinquennium ending 1955-56, on the basis of complete utilization of power from development programmes envisaged in the Five-Year Plan.

Wires and Cables

The electric wire or cable forms the conducting link between one electrical equipment and another; it also constitutes the internal veins and arteries of electrical equipment. It may be lightly insulated, as in a bell wire which connects the bell-push with the bell and the battery, or it may be heavily insulated, as in the case of an underground high voltage power cable which links the electrical generating station of a city with the suburban sub-station or supply centre. In size it ranges from a wire much finer than the human hair used for winding the coils of hearing aids, to a heavily armoured telegraph or telephone cable running along the bed of the ocean at vast depths and over long distances.

The electric wire or cable may be bare or insulated. A bare conductor is used as overhead line for telegraphy, telephony, and power transmission. When so used it is supported by, or suspended from, porcelain, glass, or other insulators attached to wood, concrete, or steel poles.

An insulated wire or cable consists of the conductor which provides the path for the electric current when the circuit is completed, the insulation or dielectric which prevents direct contact between two or more conductors or between the conductor and any other object not intended to form a part of the electrical circuit, and the preservative material for protecting the dielectric and the conductor from abrasive, corrosive, or other destructive action.

Conductors are generally made of copper, primarily because copper has a high electrical conductivity approaching that of silver, which is the best known commercial conductor of electricity. Copper has high ductility and malleability which enables it to be drawn into wires as fine

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as one-thousandth of an inch in diameter. It can also be joined with ease by such processes as soldering, brazing, and welding, and it is resistant to many forms of corrosion.

Copper for electrical conductors is produced by electrolytic deposition from cast copper plates. The grade used contains 99.9% or more of copper and is known as 'High conductivity tough pitch copper.' Electrolytic copper is cast into wire bars and rolled into rods of different sizes. Standard rod sizes for drawing wires and cables are 3/4, 5/8, 1/2, 7/16, 3/8, 5/16, and 1/4 inch in diameter.

Aluminium conductors are frequently used for bare overhead power lines. The electrical conductivity of aluminium is approximately 61% of that of an equal section of copper. Due to the lower specific gravity of aluminium, the weight required for equal conductivity is 50% of that of copper. Its maximum tensile strength is only about 50% of that of copper and when aluminium is used for overhead lines, shorter spans with a larger number of pole supports are required. Aluminium has lower corrosion resistance than copper. Aluminium conductors are not used in insulated cables because larger quantities of insulating and protective materials are required for covering the conductor, which should necessarily be of much larger dimensions than copper, and cable construction with aluminium wires is uneconomic under most circumstances.

Composite conductors—A combination of high tensile galvanized steel wires around which aluminium wires are stranded—A.C.S.R. (aluminium conductor steel reinforced)—is frequently used for high voltage overhead lines carrying large banks of power. The use of such composite conductors for overhead lines enables longer spans to be used and appreciable economy in line construction is effected. Steel-cored copper conductors consisting of circular copper wires round a core of high tensile galvanized steel wires are sometimes used, but the combination is economic only when copper prices are low. Copper-clad steel or 'copperweld' is produced by casting copper round a steel bar, rolling into rods, and drawing into wires. The resulting conductor is somewhat inferior to copper and superior to steel. It is used for telegraph, telephone, or overhead earth wires.

Galvanized steel conductors are used for telegraph and telephone lines and occasionally for rural distribution overhead lines where the load to be carried is small and the voltage drop is of little consequence. For field telephone cables where the current to be transmitted is small and a high degree of tensile strength is required, a composite conductor of tinned or galvanized steel and tinned copper wire is frequently employed. Such field telephone cables

are insulated with rubber or polyvinyl chloride (P.V.C.) dielectric.

Overhead wires for electric railways and tramways, and for trolley bus services, where the electric supply to the vehicle is by pantograph or trolley from a bare wire, cadmium-copper (Cd content, 0.8–1.0%) is employed. Cadmium-copper possesses high resistance to abrasion.

Stranded wire—For both bare and insulated conductors, stranded wire is preferred to single wire. Stranded wire is flexible and is less liable to kinking and breaking.

Stranded wires are made by twisting a number of wires together to form layers, the wires in each layer being laid helically round the previous layer. Successive layers are stranded in opposite directions. The wires are twisted with a uniform lay, the lay being the distance along the length of the strand in which the wire makes a complete convolution; in other words, it is the distance measured along the strand between successive twists of any one wire.

Electrical conductors of high flexibility are made from a large number of wires of small diameter 'bunched' or twisted together without any definite geometrical formation. The finer the diameter of the constituent wires the greater the degree of flexibility.

Flexible conductors required for welding cables, cables for mobile cranes and coal cutting machines, and generally for purposes requiring rough usage, are stranded in the same manner as ropes.

Insulating materials

The dielectric for insulation is selected according to the purpose for which the cable is required. The more common materials employed are given in Table 102.

Protective materials

Paper-insulated cables are generally used in sheathed (with lead, lead alloy, or aluminium) form. If required for use underground or in situations in which mechanical damage is likely to be caused, they are armoured with galvanized steel wires or tapes. Fibrous materials impregnated with weather-proofing compositions are used as bedding under the armour and for final 'serving.'

Rubber-insulated cables are protected by cotton tape and fibrous braiding impregnated with weather-proofing compositions. They may be also sheathed with lead or lead alloy with or without armour. Tough rubber sheathing is the finish most frequently used for heavy duty portable rubber cables.

Guttapercha-insulated cables are armoured with galvanized steel wires.

TABLE 102—COMMON INSULATING MATERIALS FOR CABLES

| | |
|--|---|
| Paper impregnated with resin, oil or petroleum base; dry paper insulation is used for high voltage work, the cable being filled with an inert gas under pressure | For street mains, long distance transmission, and power supplies in industrial undertakings or mines |
| Rubber (natural or synthetic) | All forms of portable cable; wiring of dwelling houses, offices, places of entertainment, etc.; street lighting; railway signalling |
| 3. Guttapercha | Submarine telegraph cables |
| 4. Paper wrapped loosely round conductors to occlude air | Telephone and telegraph cables, usually underground |
| 5. Varnished cambric | Power cables as in (1) |
| 6. Polyvinyl chloride (P.V.C.) | Dwelling houses, etc. as in (2); telephone switchboards |
| 7. Vulcanized bitumen | Once used for street mains and mines; now seldom used |
| 8. Mineral (magnesia) | Copper sheathed and used in hot situations, e.g., boiler houses |
| 9. Polythene | High frequency work; telephone, telegraph, radio, and radar |
| 10. Cotton | For winding generators, motors, transformers, and similar electrical equipment |
| 11. Silk | |
| 12. Enamel | |
| 13. Paper | |
| 14. Glass fibre | |
| 15. Rayon | |
| 16. Asbestos | |

Dry core telephone cables and varnished cambric cables are finished in the same manner as paper-insulated cables. For internal use under dry conditions an impregnated fibrous braiding is employed for varnished cambric cables.

P.V.C. cables are used as such or with P.V.C. sheathing. They may also be finished with impregnated fibrous braiding.

Mineral-insulated cables are used without any protection over the copper sheathing.

THE INDIAN INDUSTRY

The first factory in India for the manufacture of electric wires and cables was started at Tatanagar in 1922 by the *Indian Cable Co. Ltd.* Bare copper conductors, rubber-insulated cables, and cotton-covered winding wires were being produced in the early stages. The output of the factory was insufficient to meet the country's requirements. With the decline in imports and the considerable increase in demand for cables during World War II, the need for another factory was felt. The *National Insulated Cable Company of India Ltd.*, Mehgaon (near Jubbulpore) was established in 1942 and production started in May 1943; the factory was shifted to Shamnagar (West Bengal) early in 1945. Bare copper conductors, steel-cored aluminium conductors, rubber-insulated cables and flexibles, cotton-covered winding wires, and enamelled wires are produced in this factory. The production capacity of the *Indian Cable Co. Ltd.*, Tatanagar was increased during the war and the annual production of bare copper wires rose to 10,000 tons and the finished yardage of rubber-insulated cables to 30

million yards per annum. A second factory was established at Tatanagar by the Government of India during the war to meet defence requirements for signalling cables. This factory, which was designed to produce rubber-insulated field telephone cables at the rate of 800 miles per week, actually attained a regular production of 1,136 miles per week. The production was stopped after the war and the equipment was taken over by the *Indian Cable Co. Ltd.* A.C.S.R. conductors are being produced by the *Aluminium Industries Ltd.*, Kundara (Travancore) since March 1950. Plastic-insulated cables are produced by the *Radio and Electricals Manufacturing Co. Ltd.*, Bangalore. This factory with 18 extruding machines went into production in 1950. Copper conductors secured from outside sources are insulated with polyvinyl chloride (P.V.C.) in this factory.

Table 103 gives the installed capacities of

TABLE 103—INSTALLED CAPACITY FOR WIRES AND CABLES

| | Pre-war | 1952 |
|--|------------|------------|
| Bare copper conductors (tons) | 7,200 | 20,000 |
| A.C.S.R. conductors (tons) | .. | 4,500 |
| Rubber-insulated cables and flexible (yds) | 20,000,000 | 45,000,000 |
| P.V.C.-insulated cables (yds) | .. | 5,004,000 |
| Winding wires (tons) | 200 | 450 |

ELECTRICAL INDUSTRIES

TABLE 104—PROJECTED CAPACITY OF DRY CORE CABLES FACTORY*

| | Qty (miles of cable) |
|---|-------------------------|
| Unit type subscribers' cable : | |
| 6.5 lb./mile unarmoured | 55 |
| 10 lb./mile unarmoured | 5 |
| 10 lb./mile half armoured and half unarmoured | 59 |
| 10 lb./mile armoured | 180 |
| 20 lb./mile armoured | 20 |
| Star-quad trunk type cable : | |
| 40 lb./mile armoured | 150 |
| Total | 469 |

* The Planning Comm. Programmes of Industrial Development 1951-56, 1953, 94

TABLE 105—PRODUCTION CAPACITY OF INDIAN CABLE INDUSTRY IN 1955-56*

| | |
|---|-------|
| Telegraph and telephone wires and cables (million ft.) | 2.5 |
| A.C.S.R. cables (tons) | 5,000 |
| Insulated aluminium conductors (tons) | 500 |
| Winding wires (tons) | 1,100 |
| Rubber and plastic insulated cables and flexibles (million yd.) | 119 |
| Paper-insulated power cables (miles) | 400 |

* The Planning Comm. Programmes of Industrial Development 1951-56, 1953, 95

different factories for the production of various types of cables.

Paper-insulated cables required for power and telecommunication purposes are not being produced in the country. The Government of India are understood to have entered into technical agreement with the *Standard Telephone and Cables Ltd.* of U.K. and are setting up a factory, *Dry Core Cables Factory*, at Rupnarainpur (West Bengal) for the manufacture of dry-core paper-insulated, air spread, lead-covered cables. The factory which is expected to be completed by 1953-54, will be able to manufacture communication cables worth Rs. 80-100 lakhs per annum. The *Indian Cable Co. Ltd.* have also under consideration a scheme for the manufacture of copper rods, plastic wires and cables, enamelled wires, and other types of cables not hitherto manufactured in the country.

Table 104 gives the productive capacity of different types of cables envisaged by the *Dry Core Cables Factory*.

The *Indian Cable Co. Ltd.* have plans for the production of paper-insulated power cables.

When the factory of the *Aluminium Industries Ltd.* reaches the full rated capacity it will, together with the *Indian Cable Co. Ltd.* and the *National Insulated Cable Co. of India Ltd.*, satisfy the

country's requirements for aluminium conductors, estimated by the Central Electricity Commission at 5,000 tons per year. The *Aluminium Industries Ltd.* proposes to instal a rolling mill at Kundara for the production of $\frac{3}{8}$ in. aluminium rods and have also under examination a scheme for the manufacture of insulated aluminium conductors for which the demand is estimated at 500 tons per annum.

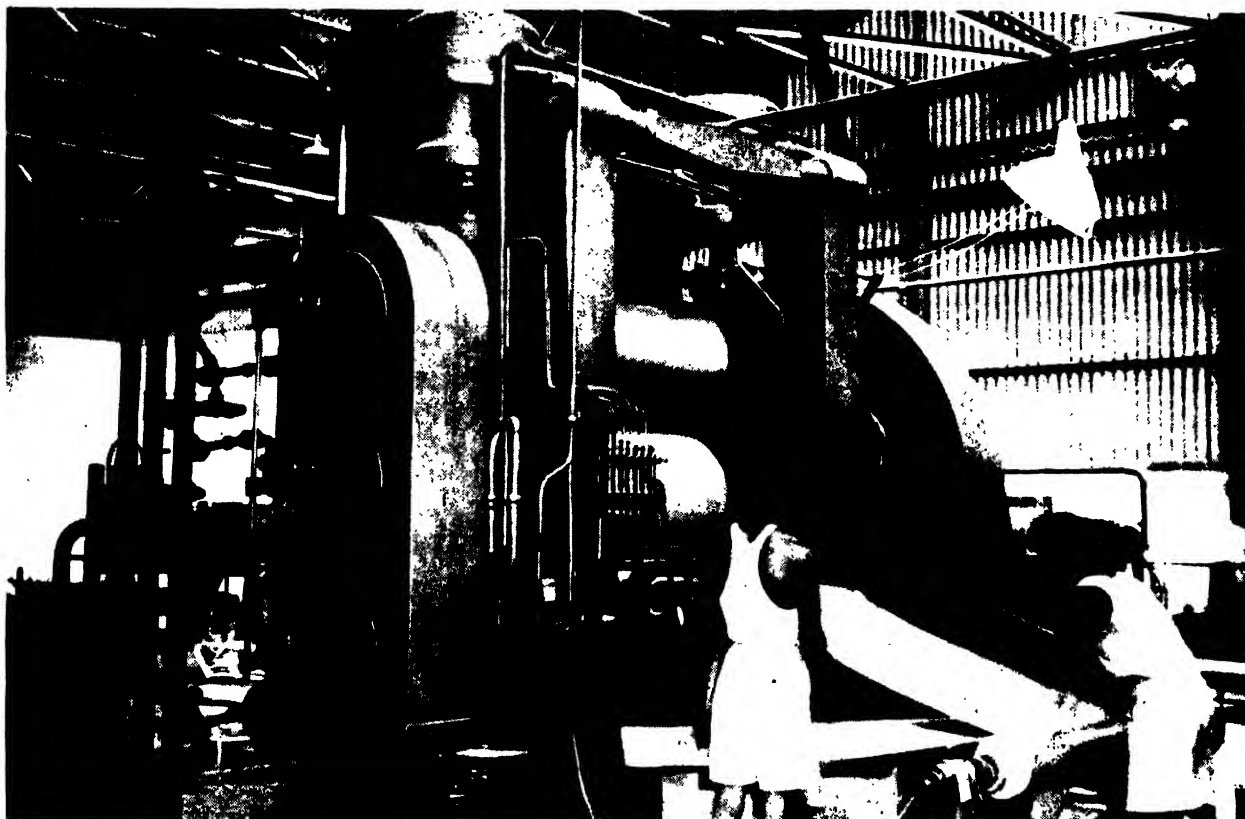
The estimated annual rated capacity of the industry for the production of different types of cables is given in Table 105.

Raw materials

Prior to World War II the *Indian Cable Co. Ltd.*, which was the only manufacturer of cables at the time, was importing hot-rolled electrolytic black copper rods for the manufacture of cables. Copper rods are now produced by the *National Rolling Mills Ltd.*, Calcutta and a rolling mill is now being installed at Tatanagar by the *Indian Cable Co. Ltd.* for the production of rods. Copper is imported in the form of cast wire bars, each weighing 250 lb. and hot-rolled to rods (diam., $\frac{3}{8}$ - $\frac{1}{2}$ in.). For the production of A.C.S.R. wire electrolytic aluminium (Al content, 99.5%) of c. 66% conductivity is imported in the form of $\frac{3}{8}$ in. rods in coils, each weighing 112 lb. Galvanized steel wire required for A.C.S.R. range from 1/5 inch to 1/20 inch in diam. and the entire requirements are imported from U.K. Pure tin, used for tinning copper for rubber-insulated cables, is also imported.

Rubber used for insulation and sheathing is obtained from indigenous sources. Smoked sheet RMA IX and Pale Latex Crepe are used; the latter has high insulation resistance. Alkali reclaimed rubber is also used along with natural rubber for insulation purposes. Polyvinyl chloride and enamels are imported. Imported lead used for sheathing has the following composition: Pb, 99; Sn, 0.4; and Sb, 0.2%.

High quality calico, proofed on one side, is employed for taping. Varnished cloth (thickness, 5 mils) is used for weather-proof taping; it is applied above the calico taped core. Cotton yarn of 40's and 2/30's is used for braiding taped, braided, and compounded (T.B.C.) rubber-insulated cables. Flexible cords are braided with glaze or mercerized cotton of different fast shades, the sizes ranging from 2/60's to 1/120's. Egyptian combed cotton yarn of 60's to 120's is used for winding copper wires. The ply of the yarn varies with the thickness of covering required and the gauge of the wire. Cotton tape and yarn conforming to standard specifications are manufactured in the country. Asbestos yarn used for braiding fire-resisting T.B.C. cables and galvanized steel for rubber-insulated flexible cords are imported.



Indian Cable Co. Ltd., Tutunagar

FIG. 77—A RUBBER CALENDER FOR SHEETING RUBBER

Preservatives for the protection of cables comprising special waxes, paraffin wax, microcrystalline waxes, Seekay wax (for flame-proofing), and red lead compounds (for weather-proofing) are imported.

Table 106 gives the quantities of imported raw materials required for the annual production of 7,000 tons of bare copper conductors, 1,400 tons of winding wires, 80 million yards of rubber-insulated cables and flexibles, 5,000 tons of A.C.S.R. cables, and 20 million yards of plastic-insulated cables and flexibles.

TABLE 106—QUANTITIES OF RAW MATERIALS REQUIRED*

| | Qty |
|---|-----------|
| Electrolytic copper rods (tons) | 10,000 |
| Lead ingot (tons) | 1,200 |
| Cotton yarn (tons) | 190 |
| Calico cloth of 40 in. width (yd.) | 1,071,700 |
| Polyvinyl chloride (tons) | 190 |
| Electrolytic aluminium rods (tons) | 3,060 |
| High tensile galvanized steel wire (tons) | 1,250 |

* The Planning Comm. *Programmes of Industrial Development 1951-56, 1953, 92*

Manufacture

Wire drawing—Copper rods as received are covered with a tough scale of black copper oxide. The coating is removed by pickling in dilute sulphuric acid or dilute hydrochloric acid before the drawing operation. Aluminium rods are also covered with a layer of oxide, but the oxide film does not scour the dies and aluminium rods are not pickled before drawing.

Pickled copper rods are drawn through single die bull-blocks for wires up to S.W.G. The rods are drawn through tungsten carbide dies and wires (drawn at the rate of 150-600 ft. per minute) are coiled. Single die horizontal blocks are used for drawing wires of 2 S.W.G. and above.

Heavier gauge wires are drawn in continuous, multiple die, tandem wire-drawing machines through tungsten carbide dies. These machines contain from 3 or 4 dies (for the larger finished wire sizes) to 9 dies for sizes of c. 0.06 in. diam. Finishing speeds vary from 1,000 to 3,000 ft. per minute according to the sizes drawn. The reduction in the area of copper per die usually varies from 20 to 25%. The wire is drawn through each die by a power driven drum and coiled. It is fed

to the next die and coiled in the following power driven drum, and so on. The size of the wire is progressively reduced till the wire emerging from the last die is of the required cross-section. The peripheral speeds of drums are increased with each reduction and appropriate dies selected to match the peripheral speeds.

For drawing wires to sizes finer than 0.06 in. diam., cone-type machines with diamond dies are employed. As many as 25 dies may be accommodated in one machine, but machines with 12-17 dies are more common. Finishing speeds range from 5,000 to 8,000 ft. per minute for medium-fine sizes and up to 4,000 ft. per minute for fine sizes.

Tungsten carbide dies are seldom used for wires finer than 0.055 inch in diam and diamond dies are seldom used for wires larger than 0.06 inch in diam.

Copper wires are cold drawn with adequate supply of aqueous lubricant to cool both wires and dies. A continuous film of lubricant is maintained on the wires during their passage through dies. Lubricants in paste, powder, or solid form, held in boxes in front of the dies, are used for bull-blocks. A mixture of soap and tallow is used for copper wire drawing, and tallow, mineral oil, or compounded oils and greases are used for drawing aluminium wires. Multiple die machines are wet lubricated and die blocks, drums, and running wires are cascaded with lubricating solution. An aqueous solution of the lubricant is used in copper wire drawing, and oil bases, emulsions of beef tallow, compounded mineral oils, and proprietary drawing paste emulsions are used for aluminium wires; oils give brighter and better finishes than emulsions.

Annealing—Copper wire obtained by cold working is hard and springy; it has high tensile strength. It is used, without annealing, for overhead lines. For insulated cables 'bright annealed' wire is required. Annealing restores the ductility which is reduced during the cold drawing operation. Annealing is carried out by heating the wire in an inert or oxygen-free atmosphere.

Tinning—Bright annealed wire is tinned for the fabrication of vulcanized rubber-insulated cables. Sulphur is essential for the vulcanization of rubber and a film of tin is deposited on the copper wire to eliminate direct contact of sulphur with copper. Direct contact between copper and rubber should be prevented firstly because copper acts as a catalyst for the oxidation of rubber and secondly because sulphur tarnishes copper in the vulcanization process. Tinning is carried out by cleaning the wires in a dilute solution of sulphuric acid, applying flux, and running the wire through a bath of molten tin. Excess of tin is wiped off and the wire cooled before coiling or



Aluminium Industries Ltd., Kundara

FIG. 78—VIEW OF A 7-WIRE STRANDER

reeling. Conductors for P.V.C.-insulated cables are also usually tinned.

Stranding and bunching—Two types of stranders are employed—the sun and planet type, and the tubular type. In the former, bobbins or spools of wire are charged in two or more cages which can be rotated independently in either direction. As the machine operates the cages revolve round the central wire which moves forward and layers of wires are formed on the central wire. For alternate layers the cages are rotated in opposite direction. In the tubular type strander, bobbins are carried in cradles inside a tube. In the usual stranding operation a single wire is used as the base; it is wound first with 6 wires, followed by multiples of 6 in subsequent operations, i.e. 6 wires are first wound round the wire, followed by 12, 18, 24, etc. Sometimes a stranded conductor containing wires is employed as base. Stranded conductors are designated by numbers, such as 19/13 or 19/0.092, the first number indicating the total number of wires in the strand and the second the S.W.G. or the diameter (in inch) of individual wires.

Individual wires are bunched for the fabrication of flexible cords and cables. A number of fine wires are laid parallel and twisted. No central wire or strand is employed in bunched construction.

Insulation—The composition for rubber-insulated cables is prepared by masticating rubber in a mill with waxes, fillers, reinforcing agents, colours (for multicore cables), accelerators,

anti-oxidants, and vulcanizing agents. The plastic composition is applied over the conductor by longitudinal lapping, or by extrusion process and vulcanized. For application by extrusion the composition is used as such, while for application by lapping, it is sheeted in a calender and slitted into strips of the required width.

Rubber insulation is applied to small sized cables by the longitudinal process. Rubber tapes from rolls are drawn between pairs of grooved steel rolls with the conductor between them when the insulation is pressed round the conductor. The insulated wire as it is drawn forward is covered with further layers of insulation by similar pairs of rolls fitted down the machine. The insulated conductor from the final roll is hauled on the take-off drum. Insulation can be applied simultaneously to a number of conductors in a single machine. Insulated cables are lapped with a proofed cotton tape before vulcanizing.

Insulation is applied to large sized conductors with the aid of a lapping machine in which the conductor is passed through a number of heads each provided with revolving spindles carrying rubber tape rolls. The tape is wrapped spirally round the conductor. The lapping is right- and

left-handed at alternate heads. The conductor is finally lapped with proofed tape in the last two heads and the different layers are vulcanized.

The extrusion technique is applied for insulating conductors of comparatively small length. The conductor is run through a die and the rubber compound is pressed round it. The insulated conductor is turned round a haul, off the drum, from which it is wound in trays containing French chalk. Prior to vulcanizing the cables are draped with a proofed cotton tape.

Rubber-insulated cores, wound on cylinders or coiled in metal trays, are loaded in trucks and pushed inside a vulcanizer consisting of a steam-jacketed autoclave. The vulcanization is carried out at a steam pressure of c. 40 lb./sq. in.

P.V.C. insulation is applied to copper conductors in a screw type extrusion machine. Polyvinyl chloride powder is fed to the vibrating hopper of the machine. The powder is forced by a worm drive into an electrically heated barrel. The conductor is hauled through a cross-head die at right angles to the barrel. As it passes through the die the molten plastic is extruded from the barrel, the diameter and thickness of the plastic coating being determined by the size of the die



Indian Cable Co. Ltd., Tutunaga

FIG. 79—LONGITUDINAL RUBBER-INSULATING MACHINE

through which the insulated cable leaves the extruder.

Winding wires are insulated either by covering with cotton or silk yarn or by enamelling. Yarn is lapped spirally in one or more layers on the wire in high speed covering machines, the alternate layers being wound in opposite directions. The lapping mechanism is carried on a horizontal disc rotating at high speed. The cheese containing the yarn has two movements: it rotates round the conductor at the same speed as the yarn is lapped on the wire; it also rotates on its hollow spindle to allow the yarn to be pulled off. A specially shaped device, called the 'eye,' is fitted to the top of the hollow spindle to flatten out the yarn and guide it to the end. Double coverings are applied simultaneously by two lapping heads, one above the other, the covered wire passing vertically upwards. The rate of travel of the wire relative to the speed of rotation of the lapping head is adjusted according to the diameter of the wire to keep the lay constant. Depending on the thickness of the cotton or silk covering, insulated wires are classified as 'ordinary' and 'fine'.

Enamelled wire used for winding purposes is prepared by passing the conductor through a trough of liquid enamel, then through a pad of felt which wipes off the excess, and finally through a long oven for drying and baking. Several coats of enamel may be applied, each layer being dried and baked before applying the subsequent layer.

Cabling--Rubber- and P.V.C.-insulated cables are often made up of 2, 3, or 4 cores. The cables are laid up with jute worming or packing to make a circular formation. Cables meant for lighting circuits in houses, offices, public buildings, etc. are made of 2 or 3 insulated cores laid side by side without twist. They are known as 'flat twin' or 'flat three' core cables. Certain flexible cords are made by twisting the cores after giving them a protective covering.

Protective covering--Rubber-insulated cables are protected by taping, braiding, tough rubber sheathing, lead sheathing, bedding and serving, armouring, and compounding. P.V.C.-insulated cables are sometimes protected by P.V.C. sheaths. Some types of overhead conductors are cotton braided.

Rubber-insulated cables are spirally covered with cotton tape proofed on the outer surface. The tape eliminates fraying when the cable is cut and acts as reinforcement and bedding for the braid. Insulated cables made by the lapping process are taped on the same machine, the proofed tape being applied by the last two heads. Cables insulated by extrusion are taped by passing the core through a vertical tube at the base of which is a plate for holding the tape roll.

The end of the tape passes round a tension spindle and then to the cable. The plate revolves along with the spindle laying the tape at an angle to the cable.

Braiding is done generally with cotton yarn. In this process as the cables move vertically upwards a number of spindles carrying cotton thread spools move in such a way that the threads are interwoven round the cable or conductor. Certain types of rubber-insulated cables are braided with galvanized steel wire.

Tough rubber sheathing is applied by extruding a sheath of specially prepared tough rubber over the insulated core in a screw type extruding machine. The rubber composition, which should have good flexibility and abrasive resistance, is usually compounded with a high proportion of carbon black. P.V.C. sheathing is applied by extrusion.

Lead-sheathed cables are made by extruding lead on insulated cables. The flat or twisted core passes first through a tube mounted centrally in a die box and then through an annular space formed by the end of the tube and the inner opening of the die. A hydraulic ram forces molten lead alloy through the annular space to form a seamless sheath round the cable as it passes through the die.

Braided cables are impregnated with weather-proofing or fire-resisting compositions. Armoured cables are made by wrapping the cable with jute bedding and coiling with a single layer of galvanized steel wire. Armoured cables are sometimes wrapped with jute serve and impregnated.

Packing--Hard drawn stranded copper conductors and trolley wires are packed on wooden drums. Solid copper conductors are supplied in coils: No. 5 S.W.G. and above in coils of 360 lb.; No. 6 S.W.G. to No. 10 S.W.G. in coils of 250 lb.; and sizes below No. 10 S.W.G. in coils of 140 lb. Aluminium conductors are packed on wooden drums. A layer of kraft water-proof paper is wrapped over the cable on the reel, lagged with wooden lagging, and reinforced by steel hoop or wire.

The following types of packing are used for dynamo and instrument wires: hessian wrapped coils of 28 lb. and 14 lb. for No. 7 to No. 14 S.W.G.; hessian wrapped coils and/or cardboard reels of 28 lb. and 14 lb. for No. 15 to 23 S.W.G.; plywood reels in cardboard carton 1 lb. each and 14 lb. cardboard reels if specially ordered for No. 24-29 S.W.G.

P.V.C.-insulated wires are packed in coils of 100 or 50 yd. with durable brown paper. Paper-cored coils are packed in wooden boxes of different sizes according to the type and the quantity of product.

Types produced in India

The following types of wires and cables are

TABLE 107—TYPES OF BARE CONDUCTORS MANUFACTURED IN INDIA

| Hard-drawn solid copper conductors (S.W.G.) | Hard-drawn stranded copper conductors for overhead transmission lines strands (no.)/ diam. (in.) | Hard-drawn solid copper telegraph and telephone wires diam. (in.) | All-aluminium conductors strands (no.)/ diam. (in.) | A.C.S.R. conductors* strands (no.)/ diam. (in.) |
|---|---|--|--|--|
| 7/0 | 7/.064 | 0.0662 | 7/.0772 | 7/.059 |
| 6/0 | 3/.104 | 0.0791 | 7/.0868 | 7/.083 |
| 5/0 | 7/.080 | 0.0969 | 7/.0975 | 7/.093 |
| 4/0 | 7/.092 | 0.1119 | 7/.1093 | 7/.102 |
| 3/0 | 3/.147 | 0.1370 | 7/.1228 | 7/.110 |
| 2/0 | 7/.104 | 0.1582 | 7/.1380 | 7/.118 |
| 1/0 | 19/.064 | 0.1937 | 7/.1548 | 7/.132 |
| 1 to 40 | 3/.180 | 0.2237 | 7/.1740 | 7/.144 |
| | 19/.080 | | 7/.1953 | 7/.157 |
| | 7/.136 | | 19/.1256 | 7/.161 |
| | 7/.152 | | 19/.1330 | 7/.166 |
| | 19/.092 | | 19/.1447 | 7/.177 |
| | 7/.166 | | | 7/.186 |
| | 19/.101 | | | 13/.186 (.062) ‡ |
| | 7/.180 | | | 14/.173 (.076) ‡ |
| | 19/.109 | | | 13/.208 (.069) ‡ |
| | 7/.193 | | | 33/.100 (.75) ‡ |
| | 19/.116 | | | 37/.093 |
| | 7/.204 | | | 37/.102 |
| | 19/.124 | | | 37/.110 |
| | 7/.215 | | | 37/.118 |
| | 19/.131 | | | 37/.125 |
| | 19/.144 | | | 37/.132 |
| | 19/.160 | | | 37/.146 |
| | 19/.166 | | | 37/.157 |
| | 19/.185 | | | 61/.117 |
| | 39/.144 | | | 37/.168 |
| | 37/.162 | | | 61/.125 |
| | | | | 37/.177 |
| | | | | 61/.132 |
| | | | | 61/.139 |

* The first 13 types are made with single wire core and others with 7-wire stranded core

‡ Figures in brackets give diameters of steel wires used; in others aluminium and steel wires are of the same diameter

manufactured in India: bare copper, all aluminium, steel-wired aluminium, cotton-braided copper, rubber-insulated cable, P.V.C.-insulated cable, and winding wire

Table 107 gives the types of bare conductors produced in India.

Copper conductors for overhead power transmission are braided with 1, 2, or 3 layers of cotton braid. The sizes of wires used are 0.029 in. (3, 7), 0.036 in. (1, 3), 0.044 in. (1, 7, 9), 0.052 in. (7, 19), 0.064 in. (1, 7, 19, 37), 0.072 in. (19, 37), 0.083 in. (7, 19, 37), 0.093 in. (37, 61, 91, 127), and 0.103 in. (37, 61, 91, 127), the figures in brackets denoting the number of wires in the conductor.

Five types of rubber-insulated cables are manufactured, namely taped, braided, and compounded (T.B.C.) cables and flexibles; tough rubber sheathed (T.R.S.) cables and flexibles; lead alloy sheathed (L.A.S.) cables; armoured cables; and flexible cords.

The construction of conductors for rubber-insulated cables is the same as that used for cotton braided overhead copper conductors. Flexible cables are made by bunch stranding copper wires of 0.010 in. (140, 195, 296), 0.012 in. (97, 266, 368, 577, 705), 0.018 in. (60, 91, 117, 163, 248, 313, 416, 482, 640, 810, 1017), and 0.029 in. (121, 160, 186, 235, 312, 392, 491, 646, 792), the figures in brackets denoting the number of wires in the flexible cable. Rubber-insulated flexible cords are made from bunch stranded conductors for which copper wire of 0.0076 in. diam. is used; the total number of wires may be 14, 23, 40, 70, 110, or 162. T.B.C. cables with weather-proof compounding are manufactured with hard-drawn copper; other rubber-insulated cables and flexible cords are made with annealed wire.

Three types of flexible cords are made, namely mercerized cotton braided; taped, braided, and compounded (workshop type); and tough rubber

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sheathed. P.V.C.-insulated flexible cords are made in the following sizes: 1/.044, 3/.029, 1/.064, 3/.036, 7/.029, 7/.036, 7/.044, 7/.064, 19/.044, and 19/.064.

Winding wires are made from annealed single wires varying in size from 8 to 40 S.W.G. for D.C.C. wires, and from 18 to 40 S.W.G. for enamelled wires.

Testing—All wires and cables are tested according to British Standard Specifications Nos. 7-1946, 446-1932, 125-1947, 174-1951, and 215-1934. Annealed copper wires are tested for conductivity and elongation. The tinning test as applied to linned copper conductors consists in immersing the wire in helix form in persulphate solution for 10 minutes and estimating the loss of copper colorimetrically.

Rubber-insulated cables are subjected to voltage, insulation resistance, and spark tests both in the core and finished stages. They are first subjected to voltage test; if the cables do not have a metallic sheath to serve as an earth for testing purposes, they are immersed in water for at least 12 hours prior to the test. While still immersed, an a.c. voltage of 1,500 volts for 250 volts grade and 3,000 volts for 660 volts grade cable is applied gradually between the conductor and the water

which is earthed and the voltage maintained for 15 minutes. Cores withstanding the voltage are tested for insulation resistance by high sensitivity mirror galvanometers after passing d.c. current of not less than 500 V through the core for one minute. Finished cables are also subjected to the voltage test. The voltage is applied between the conductor and the earth (the cable is not required to be immersed in water for this test). Cores failing in the voltage test are subjected to the spark test for the location of faults or weak spots. The faults are repaired and the cable again subjected to the voltage test. Rubber- and P.V.C.-insulated cables are submitted to high voltage spark test during processing. Enamelled copper wires are subjected to electrical, mechanical, and chemical tests.

Production and trade

Table 108 gives the production of electric wires and cables in India.

Imports—The major part of India's requirements of electric wires and cables was met by imports mainly from U.K. before the war. Table 109 gives the imports into India. Table 110 gives the imports from U.K. during the period 1949-51.

TABLE 108—PRODUCTION OF ELECTRIC WIRES AND CABLES

| | Bare copper conductors (tons) | A.C.S.R. conductors (tons) | Rubber-insulated cables and flexible (yd.) | Winding wires (tons) | P.V.C.-insulated cables (yd.) |
|---------|-------------------------------|----------------------------|--|----------------------|-------------------------------|
| Pre-war | 3,600 | .. | 8,000,000 | 120 | .. |
| 1943 | 7,500 | .. | 20,500,000 | 190 | .. |
| 1946 | 7,856 | .. | 22,609,723 | 211 | .. |
| 1947 | n.a. | .. | n.a. | n.a. | .. |
| 1948 | 5,880 | .. | 22,000,000 | 330 | .. |
| 1949 | 5,723 | 30 | 19,356,274 | 340 | .. |
| 1950 | 5,676 | 1,420 | 33,868,537 | 248 | 1,872,980 |
| 1951 | 2,996 | 1,720 | 41,086,585 | 296 | 3,475,000 |
| 1952 | 5,929 | 2,381 | 32,867,125 | 398 | 3,600,000 |

TABLE 109—IMPORTS OF ELECTRIC WIRES AND CABLES

(Val. in lakh Rs.)

| | Rubber-insulated | Insulations other than rubber | Telegraph & telephone wires and cables | Bare copper wire other than telegraph & telephone wires | Total |
|-----------------------|------------------|-------------------------------|--|---|--------|
| 1934/35-1938/39 (av.) | 36.40 | 53.32 | 2.71 | 13.25 | 105.68 |
| 1939/40-1943/44 (av.) | 29.47 | 43.86 | 0.92 | 10.20 | 84.45 |
| 1944-45 | 61.04 | 53.61 | 3.96 | 2.28 | 120.89 |
| 1945-46 | 77.03 | 91.37 | 2.26 | 9.75 | 180.41 |
| 1946-47 | 77.47 | 73.69 | 1.51 | 9.12 | 161.79 |
| 1947-48 | 188.17 | 81.64 | 4.49 | 11.73 | 286.03 |
| 1948-49 | 150.43 | 268.16 | 3.49 | 2.85 | 424.93 |
| 1949-50 | 94.83 | 421.64 | 34.70 | 1.92 | 553.09 |
| 1950-51 | 123.84 | 196.63 | 80.54 | 2.12 | 403.13 |
| 1951-52 | 51.95 | 250.40 | 3.46 | 3.51 | 309.32 |
| 1952-53 | 78.04 | 607.61 | 10.17 | 11.58 | 707.40 |

TABLE 110—IMPORTS OF ELECTRIC WIRES AND CABLES FROM U.K.*

| | Qty (tons) | | | | Val. (£) | | | |
|---------------------------|------------|--------|-------|-------|-----------|-----------|-----------|---------|
| | 1948 | 1949 | 1950 | 1951 | 1948 | 1949 | 1950 | 1951 |
| Insulated cables : | | | | | | | | |
| Telegraph & telephone | 718 | 3,424 | 3,305 | 279 | 115,799 | 596,045 | 632,359 | 92,862 |
| Paper-insulated | 8,420 | 13,290 | 7,494 | 4,939 | 1,159,288 | 2,074,539 | 1,226,977 | 938,248 |
| Rubber-insulated | 3,232 | 3,706 | 2,323 | 1,394 | 836,382 | 946,792 | 632,495 | 464,946 |
| Other insulations | 696 | 1,444 | 940 | 863 | 239,609 | 486,400 | 340,252 | 412,198 |
| Uninsulated copper wire : | | | | | | | | |
| Circular, thinner than | | | | | | | | |
| No. 20 gauge | 131 | 56 | 30 | .. | 21,780 | 15,198 | 7,728 | .. |
| Circular, No. 20 gauge | 198 | 263 | 19 | .. | 28,128 | 54,600 | 6,263 | .. |
| Stranded | 112 | 28 | 62 | .. | 16,422 | 5,147 | 14,445 | .. |

* Tr. U.K.

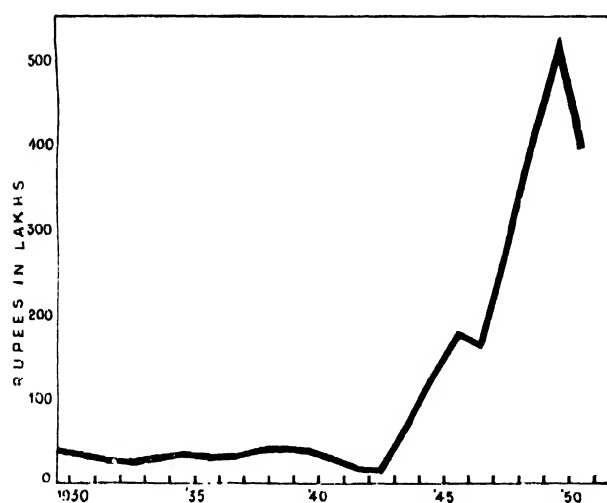


FIG. 80—IMPORTS OF ELECTRIC WIRES AND CABLES

TABLE 111—ANNUAL REQUIREMENTS OF CABLES AND WIRES IN INDIA*

| | Qty | |
|---|-------------|---------|
| | 1950-51 | 1955-56 |
| Bare copper conductors (tons) | 6,000-7,000 | 10,000 |
| Winding wires (tons) | 1,250 | 1,875 |
| Rubber-insulated and plastic-insulated cables and flexibles (million yd.) | 65-80 | 105 |
| A.C.S.R. cables (tons) | 5,000 | 8,000 |

* The Planning Comm. Programmes of Industrial Development 1951-56, 1953, 92

Table 111 gives the estimated requirements for different types of cables and wires in 1950-51 and 1955-56. •

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The deposition of relatively thin films of metals by the simple process of electrolysis — electroplating — has considerable industrial importance. It has been employed for giving decorative finishes and protective coatings for a variety of articles. Electroplating includes 'cold casting' or building up of one metal on the surface of the same or another metal for renovating worn out or under-size machine parts. It is also used for imparting new characteristics, e.g. water resistance, to machine parts. In electrolytyping or electroforming, a metal coating is deposited upon a mould to reproduce complicated contours, high re-entrant angles, and precise dimensions, configurations, or surface designs, e.g. printing plates and gramophone matrices. Electrolytic processes are employed also for anodising, electro-cleansing, electropolishing, and anodic pickling.

Electrolytic processes have been employed on a large scale for the extraction and refining of metals. About three-quarters of the world's copper and about one-quarter of its lead are refined by electrolysis. Vast quantities of zinc and nickel and smaller quantities of cadmium, silver, and gold are also refined electrolytically (Thorpe, IV, 260).

The technique of electro-deposition has been extended to obtain rubber deposits from latex solutions for covering metal sheets and frames required for chemical plants. Inner tubes for motor tyres have been produced by this process. Rubber deposition takes place on the anode.

In the electroplating process, the object to be plated is made the cathode and a solution containing a salt of the metal to be deposited is used as the electrolyte; the anode may be made of the metal to be deposited or other conductor. When a low voltage direct current is passed through the solution, electrolysis takes place as a result of which the metal is deposited on the article which

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TABLE 1—QUANTITY OF METALS DEPOSITED PER AMP.-HOUR AND 1,000 AMP.-HOURS*

| | Chemical equivalent | g./amp.-hour | lb./1,000 amp.-hours |
|-------------------|---------------------|--------------|----------------------|
| Cadmium | 56 | 2.09 | 4.6 |
| Chromium | 8.75† | 0.328 | .. |
| Copper (sulphate) | 31.8 | 1.182 | 2.61 |
| Copper (cyanide) | 63.6 | 2.364 | 5.22 |
| Cobalt | 29.5 | 1.098 | 2.42 |
| Gold (chloride) | 65.6 | 2.436 | 78 oz. troy |
| Gold (cyanide) | 197 | 7.308 | 235 do. do. |
| Iron | 28 | 1.044 | 2.3 |
| Lead | 103.5 | 3.86 | 8.51 |
| Nickel | 29.3 | 1.09 | 2.4 |
| Silver | 108 | 4.024 | 129 oz. troy |
| Tin (divalent) | 59.5 | 2.21 | 4.87 |
| Tin (tetravalent) | 29.75 | 1.10 | 2.43 |
| Zinc | 32.5 | 1.22 | 2.6 |

* Thorpe, IV, 261

† Hexavalent form, CrO_3 ; † avoirdupois

forms the cathode. The thickness of the deposit depends upon the current density, the current efficiency, and the duration of deposition. The physical character of the deposit depends upon the current density, the temperature, the bath composition, the nature of the surface to be plated, and the presence or absence of 'addition agents'.

Table 1 gives the chemical equivalents of metals and the amounts deposited per ampere-hour and 1,000 ampere-hours.

In actual practice, quantitative depositions are seldom realised. Indeed, in some cases, e.g. chromium deposition, the current efficiency, which expresses the weight deposited as a percentage of that required by Faraday's law, is only c. 12.5%.

The nature of different metal platings and their applications are briefly indicated below:

Nickel—Nickel is extensively used for electroplating cycle and motor parts, sanitary fittings, gramophone parts, toys, electrical fittings, etc. Chromium plated articles are first given an undercoat of nickel. Nickel forms a non-porous coating on iron and steel, and is an ideal metal for protection against rusting and corrosion. The properties of the deposit depend upon the composition of the bath and conditions of deposition, and specialized research into the conditions which determine the quality of the deposit has led to the extended use of nickel plating. The consumption of nickel in the electroplating industry is only next to that of tin.

Nickel baths of various compositions are employed according to the purpose for which the deposit is required. For protection against corrosion and as undercoat for chromium deposition, a dull coating which can be buffed semi-bright is required. For wear resistance, a hard and tough deposit is necessary and for electroforming, a hard

but ductile deposit is preferred. For protection purposes a deposit 0.0001–0.0002 in. is sufficient; for engineering applications the thickness of the coat should be 0.06 in. or more.

Acid baths (pH, 1.5–6.0) containing nickel sulphate are used for plating. Inorganic additives, such as sulphates and chlorides of sodium, potassium, magnesium, or ammonium, are used to decrease the nickel ion concentration.

Table 2 gives the principal types of baths used for nickel deposition.

Boric acid is generally used as buffer; acetic acid and formic acid are also sometimes used. For bright nickel deposits, brighteners, such as (a) cadmium or zinc salts, formates, aldehydes, ketones, and amino polyaryl methanes and (b) cobalt salts, aryl sulphonic acids, sulphonamides, and sulphonimides, are added. The former group gives bright but brittle deposits; the concentrations for securing the required quality of deposits are critical. The latter group may be used in various proportions to modify the properties of the deposits, but they are not so effective as brighteners. Certain anti-pitting agents are also added to the plating bath to prevent the formation of pits on the cathode surface due to the evolution of hydrogen or the release of dissolved gases. Hydrogen peroxide is used for dull nickel baths and wetting agents for bright nickel baths. The bath is sometimes treated with activated carbon (Blum, 367).

Rolled and cast nickel of high purity is used for anodes. They are depolarized to ensure uniform corrosion; a small amount of carbon is added for facilitating uniform casting and for aiding corrosion. Cotton bags are provided to catch the insoluble residue of finely divided nickel, nickel oxide, and nickel peroxide released during anode corrosion.

Black nickel deposits with little or no resistance against corrosion are produced as decorative finishes on iron and steel. The article is first nickel plated and subsequently covered with black deposit. Black deposits may also be produced on copper, brass, zinc, and cadmium coated articles. A typical formula for producing black deposits is the following: $\text{NiSO}_4 \cdot 7\text{H}_2\text{O}$, 75; $\text{NiSO}_4 (\text{NH}_4)_2 \cdot \text{SO}_4 \cdot 6\text{H}_2\text{O}$, 44; $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 37.5; and NaCNS , 15 parts.

Bright nickel plating requires no buffing. Depending upon the temperature and current density employed during plating, the appearance of the deposit may be 'burnt', frosty, bright, or milky.

Chromium—Chromium is widely employed for plating on account of its hardness and non-corrodibility. It is usually applied as a thin layer over a thick, adherent, non-porous deposit of nickel. Direct application does not yield a strongly adherent deposit. It is used for coating automobile

TABLE 2—BATHS USED FOR NICKEL DEPOSITION*

| | Plain cold bath | Watt's type, warm bath | Bright nickel bath: same as Watt's bath + addition and wetting agents | High sulphated bath (direct plating on zinc or barrel plating on brass)** | For plating on magnesium | For electrotyping | For plating on electrotype† | Bright cobalt-nickel bath‡ | For hard deposits | High speed nickel bath |
|---|-----------------|------------------------|---|---|--------------------------|--------------------------------------|-----------------------------|----------------------------|-------------------|------------------------|
| Nickel sulphate ($\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$) | 120 | 240 | 240 | 70 | 60 | 70 | .. | 240 | .. | 200 |
| Ammonium chloride | 15 | .. | .. | 15 | .. | 5 | .. | .. | .. | .. |
| Boric acid | 15 | 30 | 30 | 15 | 35 | .. | .. | 30 | 30 | 40 |
| Nickel chloride ($\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$) | .. | 45 | 45 | .. | .. | .. | 135 | 45 | 300 | 175 |
| pH | 5.3 | 4.5-5.5 | 2.3-4.5 | 5.5 | 5.5 | 6.0 ¹ 5.6 ² | 4.6 | 4.5 | .. | 1.5 |
| Temp. | 20-30 | 43 | 43 | 20-30 | 40 | 20-30 | 46 | 55 | 50 | 46 |
| Current density, amp./sq. ft. | 5-20 | 20-65 | 20-65 | 14-28 | 10-30 | 10-20 | 47 | 28 | 50-100 | 100 |

* Blum, 379

** Contains also Na_2SO_4 (160 g./l)† Contains also $\text{Ni}(\text{C}_2\text{H}_3\text{O}_2)_2$ (105g./l)

‡ Contains also: cobalt sulphate, 15 g.; ammonium sulphate, 2.5 g.; formaldehyde, 2.5 g.; and nickel formate, 50 g./l

¹ For wax mould² For lead mould

parts, jewellery, and metal furniture on account of its attractive blue-white colour and resistance to wear and corrosion. Chromium deposition finds application in resizing worn out machine parts, and for increasing the life and wear-resistance of small tools and gauges. Chromium plated surfaces have an exceptionally low coefficient of friction, and reciprocating parts of machinery, such as pump rods, are usually chromium plated. Diesel engine cylinders and gun barrels are chromium plated to reduce wear and friction.

Chromium plating baths are prepared from chromic acid. Small quantities of sulphuric, hydrofluoric, and silicofluoric acids or their salts are added to aid chromium deposition. Practically all plating baths contain chromic and sulphuric acids in the ratio 100:1 or 200:1; the latter ratio gives good throwing power. Lead and antimonial lead have been employed as anodes. A bath for the electrowinning of chromium from its ores has been developed by the U.S. Bureau of Mines (Llyod *et al.*, *Trans. electrochem. Soc.*, 1946, 89, 443).

Cadmium—Cadmium is one of the best rust preventives known for steel. It is unaffected by caustic and alkaline vapours. It is used for

plating washing machines, boilers, and household equipment. Cadmium is applied direct to iron without any undercoat.

A cyanide bath prepared from cadmium cyanide, sodium cyanide, and sodium hydroxide or from cadmium oxide and sodium cyanide, is employed for cadmium plating. Furfural compounds and complex mixtures, such as wool extract, are used as brighteners. Nickel and cobalt salts are sometimes added in small quantities to concentrated baths operated at high current densities. Cadmium in cast or ball form is employed as anode. The anode and bath chemicals should be nearly free from impurities, especially from lead which is objectionable. A typical plating bath contains: cadmium cyanide, 45g./l; sodium cyanide, 120g./l; and addition agents. The cathode current density may vary from 5 to 50 amp./sq.ft.; the anode current density should not exceed 20 amp./sq.ft. The coated article is dipped in oxidizing solutions for 2-30 sec. to brighten the surface and to render it passive. The oxidizing agents employed are: nitric acid (1:1 v/v), chromic acid (Cr_2O_3 , 100 g./l and H_2SO_4 , 2 g./l), and hydrogen peroxide (70 g./l of 30% H_2O_2 and H_2SO_4 , 5 g./l).

Zinc—Electrogalvanizing or electro-deposition

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of zinc is extensively employed for protecting electric cables.

Both acid and alkaline baths can be used for deposition. Acid baths consisting of sulphate, chloride, or fluoborate of zinc are used to plate wires and sheet metals. A typical bath composition is the following: zinc sulphate, 300 g.; sodium chloride, 15 g.; boric acid, 20 g.; aluminium sulphate, 30 g.; dextrin, 15 g.; and water to 1 litre; sulphuric acid (1-3 g./l) may be added.

Alkaline baths contain cyanide, zincate, or pyrophosphate. They have better throwing power than acid baths and are commonly used to plate irregularly shaped articles. A typical alkaline bath composition is as follows: zinc oxide, 40 g.; sodium cyanide, 100 g.; sodium carbonate, 10 g.; potash alum, 10 g.; and water to 1 litre. The solution is used at a temperature of 30-40°.

High purity anodes (Zn, 99.95-99.98%) are required for use in cyanide baths. In acid baths the impurities when present in the anode remain insoluble as sludge. Zinc-mercury and zinc-aluminium-mercury anodes are also used.

A special process for plating zinc on steel wire has been developed (Tainton, *Steel*, 1936, 98, 40).

The electrolytic method has been employed on a large scale for the extraction of zinc from low-grade and complex ores.

Tin.—Tin provides an excellent protective coating for iron and steel. It is used for coating cooking kettles, food containers, refrigerator coils, and automobile parts.

A thin coat of tin on steel prior to painting greatly improves the resistance of the paint to destructive agencies and increases the life of steel. Electro-tinning of steel sheets for export purposes is cheaper than the usual greasing method; it is not necessary to remove the tin coating for using the sheets as its presence facilitates drawing and forming operations, aids soldering, and does not interfere with spot welding (Izeland, *Indian Inst. Engrs.*, 1949, 104, 1079).

The importance of the electrolytic process for tin deposition has been steadily growing; in U.S.A. it has almost the same importance as tinning by the hot-dip process.

A typical bath used for tin plating has the following composition: stannous chloride ($\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$), 30 g.; caustic soda, 25 g.; and water to 1 litre; glucose (60 g.) is added as addition agent. Pure tin is used as anode and the bath is operated at a current density of 10 amp./sq.ft. at 50°. Alkaline stannate bath containing: sodium stannate, 80 g.; caustic soda, 20 g.; and water to 1 litre, has proved useful in securing thicker and quicker deposits. Sodium stannate is being replaced by potassium stannate as the latter has higher solubility and conductivity than the sodium salt. Processes for the continuous electro-tinning of steel strip have

been recently developed in U.S.A. [Macnair, *Times Rev. Ind.*, 1949, 3 (27), 9].

Copper.—Copper is extensively used as covering for more negative and more corrodible metals, and as base coating for depositing precious metals. It is used also for its decorative effects. Copper deposits can be burnished and polished to a high finish and decorative effects can be imparted by metal-colouring processes. The film is sensitive to sulphur fumes and is quickly oxidized on exposure to the atmosphere. Copper deposition is employed in the electrotyping process, e.g. for the production of matrices from which gramophone discs are stamped. It is used also for the reproduction of steel or copper etched plates, line and half-tone blocks, and wood cuts. Copper deposition has been applied to the production of parabolic mirrors for light houses. For the refining of copper on a commercial scale, electro-deposition is the principal method employed.

Acid sulphate and alkaline cyanide solutions are used for the electro-deposition of copper. The former consists of copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) and sulphuric acid, the concentration of copper sulphate varying from 150 to 240 g./litre. The deposit is coarse-grained in the absence of addition agents. Proteins, such as glue, are employed as addition agents in copper refining; sugars are also used. Phenol as sulphonic acid is added to give smooth and hard deposits in electrotyping. For semi-bright deposits wetting agents, like Trita 720, are employed which also increase the range of current density for securing good deposits.

For the direct deposition of copper on metals which are less electro-positive than copper, such as iron, a cyanide copper bath containing sodium cuprocyanide is used. This salt is prepared from basic cupric carbonate and sodium cyanide and carbonate. Generally sulphate baths are used for electrotyping, electroforming, and immersion copper coating; cyanide baths are used for ornamental finishes and undercoats for other metals. For obtaining thick deposits a preliminary coat from a cyanide bath is followed by a second coat from an acid sulphate bath.

Lead.—Lead coatings are applied for protecting iron and steel. The electrolytic process is employed on a large scale for the refining of lead.

Dense deposits of lead are produced from fluosilicate, fluoborate, and perchlorate baths. A typical fluoborate bath contains basic lead carbonate (100 g.) dissolved in fluoboric acid (prepared from 50% HF, 225 g.; H_3BO_3 , 100 g.; and water to 1 litre); glue (0.2g.) is used as addition agent.

Iron.—Electro-deposition is employed for building up worn out machinery parts. Copper printing plates are given a coat of iron to protect them from the corrosive action of printing inks.

Ferrous ammonium sulphate (100 g./l.) rendered neutral by the addition of freshly precipitated ferrous carbonate is used for plating copper printing plates. For securing thicker deposits, particularly on plates used for printing currency notes, a solution of ferrous chloride containing hydrochloric acid has been found suitable when worked at 106° and a current density of 186 amp./sq.ft. (Thorpe, IV, 267).

Silver—Silver is extensively applied as decorative coating for table- and ornamental-ware. It readily lends itself to scratch-brushing, burnishing, and polishing.

A typical bath for silver plating consists of: silver (as cyanide), 13.7 g.; potassium cyanide, 2.7 g.; and potassium carbonate, 50 g.; water to 1 litre. A dull white deposit, which can be finished by mopping and burnishing, is obtained. Sodium salts may be substituted for potassium salts. The possibility of plating from an iodide bath has been recently studied (Ramachar & Sadagopachari, *Curr. Sci.*, 1950, 19, 284).

Steel and nickel-plated articles are coated first in a 'strike' solution containing 10 g. sodium cyanide and 0.5 g. silver cyanide, and then in the main bath. Lead, tin, and their alloys are passed directly from the hot caustic boil (for grease removal) to a weak silver solution containing free cyanide and then to the main bath. Brass, copper, and nickel-silver articles, which show a tendency to simple deposition of non-adherent silver, are 'quickened' by dipping in a solution containing mercuric cyanide in potassium or sodium cyanide (Hg, 2-3 g./l.). A small quantity of carbon disulphide is added along with Turkey Red oil as stabilizer to the plating solution for producing shining deposits.

Gold—Gold deposits of varied colour can be secured by simultaneous deposition from mixed baths containing gold salt along with copper, nickel, or silver salt. Electro-deposition is employed for the refining of gold and for the production of gold leaf and gilded wires used for ornamental braids.

A double cyanide of gold and potassium is employed for gold plating (gold cyanide, 3.4 g.; potassium cyanide, 20 g.; and water to 1 litre). The shade of colour produced is variable. Gold solutions and small currents give pale shades. Addition of copper cyanide produces 'red or rose' gold; silver cyanide gives 'green' gold; and nickel cyanide produces 'white' gold. The appearance of the deposit—smooth or matt—varies according to the nature of the surface. Gold is recovered from exhausted baths by treatment with hydrochloric acid and precipitation with ferrous sulphate.

Other metals used in commercial plating for specific purposes are tellurium, cobalt, and rhodium.

Alloy plating is not as widely employed as pure

metal plating owing to practical difficulties. For co-deposition the metals must be compatible from the metallurgical and electro-chemical points of view. Brass, solder, speculum metal, and copper-tin-zinc alloy lend themselves to deposition under suitable conditions. Steel is brass plated to secure adhesion of rubber and for ornamental purposes. Speculum metal is hard, and resistant to wear and tarnish; it has an attractive appearance. A thin deposit (0.2 mil) of copper-tin-zinc alloy imparts good protection against corrosion; the alloy is harder and more wear resistant than nickel; it is also non-magnetic and can be easily soldered. Copper-tin-zinc alloy plating known also as Bright Alloy plating, is used for shop fittings, jewellery, table-ware, cutlery, toilet fixtures, metal furniture, refrigerator, automobile head light reflectors, cigarette cases and lighters, and vacuum flasks. Other alloys occasionally used for plating are: lead-tin, lead-tin-copper, nickel-cobalt, and tin-zinc. Lead-tin deposits are used for the protection of steel against corrosion and as a running surface for bearings. Lead-tin-copper alloy is harder and more corrosion-resistant than nickel. Tin-zinc alloys of suitable compositions are deposited on steel for corrosion and rust prevention. Plated surfaces can be polished with extreme ease. This alloy plating is used for steel frames of radio sets, bolts and nuts, cycle and automobile parts, and domestic hardware.

The bath recommended for brass plating contains: copper cyanide, 26.2 g.; copper zinc cyanide, 11.3; sodium cyanide, 45.0; and water to 1 litre. Brass containing 25% zinc is used for anodes and the plating is done at 80-95°F. and 9 amp./sq. ft. current density. For bronze plating, a bath containing: sodium stannate, 37.5 g.; sodium hydroxide, 7.5 g.; copper cyanide, 7.5 g.; sodium cyanide, 90 g.; and water to 1 litre, is suitable. Bronze is used for anodes and the bath is run at 170°F. and 20 amp./sq.ft. current density. Speculum metal coating containing 50-60% copper is obtained by decreasing the copper and total cyanide contents and by increasing the tin content of the bronze bath. Separate anodes of copper and tin are used to replenish the bath.

Electroplating Operations

The operations employed in commercial plating may be considered under three heads: preparation of basis metal, plating, and finishing.

The article for plating should be 'prepared' by removing loose or adhering matter, scratches, etc. Sand blasting, tumbling, polishing, and buffing are employed for this purpose. The articles are then subjected to physical and chemical cleaning operations to remove grease or soil, foreign particles derived from polishing and buffing compounds, and metallic oxides.

Grease and oil contaminants are removed by

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solvent cleaning or vapour degreasing, emulsion cleaning, cleaning with alkali, or electrolytic cleaning. In the solvent cleaning process, the article is immersed in hot trichloroethylene, dipped in clean condensed liquid to cool, and suspended in the vapour from the boiling solvent; tetrachloroethylene and perchloroethylene are also employed. Degreasers are equipped with sprayers to loosen adhering solid particles. Emulsion cleaning is more efficient than solvent cleaning for removing solid particles. The articles are immersed in or sprayed with an emulsion of the solvent and a wetting agent and rinsed with hot dilute alkali. Solutions of sodium hydroxide, sodium carbonate, sodium phosphate, and sodium silicate (usually metasilicate) are employed for alkali cleaning. Steel is usually cleaned with a strong solution of sodium hydroxide. Hot soap solutions are also extensively used. Sometimes, after the major part of the grease has been removed by organic solvents or emulsions, the articles are further cleaned by electrolytic processes. The electrolyte employed is generally the solution used for alkali cleaning. Cathodic or anodic cleaning or a combination of both may be employed.

Oxide coating on steel articles is removed by pickling in dilute hydrochloric or dilute sulphuric acid solution (10–30% by volume), the former being more effective though more expensive. Strip or wire steel is occasionally cleaned by electrolytic pickling, the pickled article being thoroughly rinsed with water before plating.

Acid dipping is employed for articles to be plated in an acid bath. Dipped articles are swilled in water. If plating is to be carried out in an alkaline bath the dipped article after swilling is again dipped in an alkaline neutralizing solution. A dilute solution of sodium or potassium cyanide is used for dipping if the plating is to be carried out in a cyanide bath. Articles to be coated with a metal which is more 'noble' than the basis metal, are given a 'strike' coat to prevent the deposition of rough, non-adherent coatings as soon as they are immersed in the plating solution.

For electroplating non-conducting materials, such as wood, glass, plastics, wax, guttapercha, plaster of Paris, and unglazed earthenware, the surface has to be made conducting. Highly porous substances are rendered non-porous by coating with shellac or lacquer. The articles are then coated with an adhesive and a conducting layer of graphite, copper, lead, silver, or bronze is deposited. The article is then ready for the plating bath.

Electroplating is carried out in tanks with conductor bars fixed at the top. Anodes are suspended from the outside bars connected to the positive of the generator or rectifier and the articles to be plated are hung in racks from the

central cathode or work bar. Steam pipes or immersion heaters are used for heating the bath; pipes or coils through which water can be circulated are provided for cooling.

Small articles are usually plated in inclined revolving barrels. The plating barrel is a perforated hexagonal cylinder. It rotates in a tank containing the plating solution and the anode at a speed of 10–30 r.p.m. Cathode contacts are built into the base of the barrel so that the articles are plated as the barrel slowly revolves. Cleaned articles are put into the barrel. During the rotation, the articles tumble over continuously exposing a fresh surface for plating. The plating efficiency is low because only a part of the charge is in circuit at any one time, and only a small part of the surface is effective. The plating solution should have a high metal content, good conductivity, and good throwing power.

Plated articles are removed from the solution and swilled first in cold running water and then in hot water. The articles are dried and finished on 'mops' and 'compos' using mild abrasives such as Tripoli and rouge. Articles plated with brass, copper, cadmium, tin, zinc, silver, and gold are scratch-brushed prior to polishing with wire wheels. For securing heavier deposits, plated articles after scratch-brushing are plated again.

Raw materials and accessories

Tanks used for various operations are made of wood or steel. Tanks made of seasoned wood and coated with pitch are used for rinsing. Welded steel tanks are used for alkaline cleaning baths and for cyanide plating. They are usually lined inside with wired sheet glass, rubber, ebonite, or synthetic plastics for insulation. Tanks used for acid copper and chromium baths are lined with lead or acid-proof bricks. Stoneware tanks are used for dips containing nitric acid. Enamel-lined tanks are used for small-scale operations.

Motor generators producing d.c. current at 6–12 volts, with adequate current output as determined by the area of the work and the current density, are required for electroplating shops. Rectifiers are employed with a.c. supplies to obtain the d.c. for plating purposes. The anode is generally made of the same metal as the one to be deposited so that the concentration of the metal ion in the bath is maintained. Certain platings require the use of 'insoluble anodes', the metal being plated from a dissolved salt in the plating bath. In some cases, a combination of 'insoluble' and 'soluble' anodes is employed, e.g. cadmium cyanide bath for which both cadmium and steel are used as anode so that anodic solution and cathodic deposition, which occur at different rates, may be balanced.

Mechanical accessories used in plating shops

include polishing wheels, mops, and hair and wire brushes.

Among the chemical accessories required for electroplating are abrasive and polishing compounds; cleaning, pickling, and degreasing chemicals; and electroplating chemicals.

Sand paper and cloth, emery paper and cloth, emery powder and flour, are used for abrasive purposes. Pumice powder, Tripoli powder, emery, and patented products like Peerless Polish, Lustre Tripoli Composition, and various grades of rouge are used for polishing.

Soda ash, caustic soda, sodium silicate, trisodium phosphate and other patented salts are used for cleaning. Hydrochloric and sulphuric acids are used for pickling; organic solvents, like trichloroethylene and benzene, are used for degreasing.

Plating baths are made from a number of ingredients: a salt or an acid solution containing the metallic ion or radical; an addition salt for increasing the conductivity, if the salt is not sufficiently conducting; a material to increase anode corrosion and prevent passivity; 'addition agents' for controlling the nature of the deposit; and a buffer to maintain the pH of the bath at the proper level. Some baths contain all the

ingredients, while others contain only some of them. Other chemicals used in electroplating are: salts for stripping nickel and chromium from electroplated articles, oxidizing salts, 'quicking' salts, passivating substances, chromating agents, and bronzing solution. Electroplating chemicals are sold under different trade names (Mantell, 1950, 229).

Plating Baths

Electroplating baths in common use contain sulphates or chlorides of the metal, double cyanides, and fluoborates, pyrophosphates, sulphamates, sulphonates, acetates, and other complex salts. Organic salts, such as tartrates and citrates, are added.

For securing satisfactory deposits, electroplating solutions should (1) be of high metal content with, in some cases, low metal ion concentration, (2) have good conductance, (3) be stable in contact with the metals to be coated, and not be precipitated on the metals by simple immersion, (4) be stable to atmospheric conditions, (5) bring about the solution of the anode so that the metal content of the solution may be constant, (6) yield

TABLE 3—COMMON ELECTROPLATING BATHS*

| Metal or alloy | Bath | Anode | Cathode current density (amp./sq. ft.) | Temp. °C. | Av. current efficiency % |
|----------------|-----------------------|-------|--|-----------|--------------------------|
| Brass | Cyanide | Cu-Zn | 2-3 | 32-45 | 80 |
| Cadmium | Alkaline cyanide | Cd | 10-50 | 20-30 | .. |
| Chromium | Chromic acid | Pb | 100-300 | 40-50 | 12-20 |
| Cobalt | Sulphate | Co | 30-165 | 20-30 | 95-98 |
| Copper | Acid sulphate | Cu | 15-40 | 25-50 | 97-100 |
| | Alkaline cyanide | Cu | 3-14 | 35-40 | 30-60 |
| | Rochelle-cyanide | Cu | .. | .. | 40-70 |
| Gold | Cyanide | Au | 1-5 | 60-80 | 70-90 |
| Indium | Cyanide | In-Pt | .. | .. | 30-50 |
| Iron | Chloride | Fe | 100-180 | 90-110 | 90-98 |
| | Double sulphate | Fe | 20-30 | 20-30 | 95-98 |
| Lead | Fluoborate | Pb | 5-20 | 20-30 | 98-100 |
| | Perchlorate | Pb | 20-30 | 20-30 | 95 |
| Nickel | Single sulphate | Ni | 5-20 | 20-30 | 94-98 |
| | Double sulphate | Ni | 3-6 | 20-30 | 94-98 |
| | Sulphate-chloride | Ni | 14-50 | 50-60 | 94-98 |
| Palladium | Chloride | Pd | 10 | .. | 98-100 |
| Platinum | Phosphate | Pt | 1 | 70 | .. |
| Rhodium | Sulphate or phosphate | .. | 20-80 | 40-50 | 10-20 |
| Silver | Cyanide | Ag | 3-8 | 15-25 | 98-100 |
| Tin | Alkaline stannite | Sn | 10 | 50 | .. |
| | Alkaline stannate | Sn | 5-15 | 60 | 70-95 |
| | Acid sulphate | .. | .. | 20-30 | 90-95 |
| Zinc | Sulphate | Zn | 12-30 | 20-30 | 99 |
| | Sulphate (hot) | Zn | 80-100 | 50-60 | .. |
| | Chloride | Zn | 40-100 | 20-40 | .. |
| | Alkaline cyanide | Zn | 8-20 | 40-50 | 85-90 |

* Mantell, 1950, 232

ELECTROPLATING

compact and adherent deposits, and (7) possess the power of 'throwing', i.e. the power of producing relatively uniform deposits (Thorpe, IV, 261).

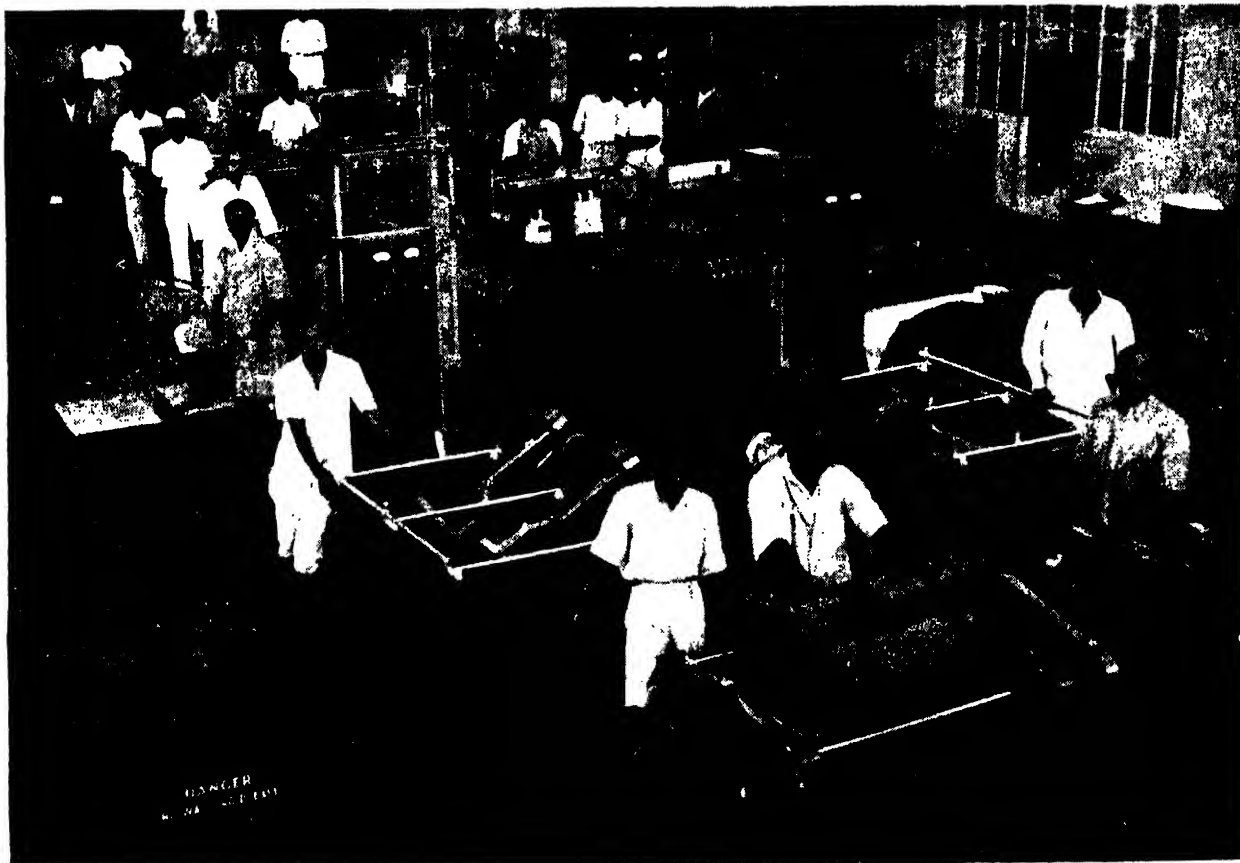
Table 3 gives the characteristics of baths employed for different types of electroplating.

THE INDIAN INDUSTRY

Well laid-out plating shops are attached to railway, telegraph and telephone workshops, ordnance factories, and industrial establishments engaged in the production of cycle and automobile parts. Electroplating works have been established in the larger cities, and undertake a variety of jobs, such as plating of surgical instruments, hospital equipment, electrical and hardware fittings, and presentation articles. The more important plating works are: the *Great Eastern Electroplaters Ltd.*, Allahabad, *India Industrial Works Ltd.*, Howrah, *Kohinoor Electro Gilders*, Bombay, the *West Coast Electroplating Co. Ltd.*, Ernakulam, and *Universal Chrome Plating Works*, Bombay. Electroplating as a finishing treatment is carried out by manufacturers of metal ware and jewellery in cities like

Aligarh, Moradabad, Mirzapur, Banaras, Surat and Delhi. In addition, there are a large number of plating shops of the 'garage' or 'out house' type scattered in towns all over the country.

Nickel and silver plating is carried out on an extensive scale in Moradabad (U.P.) for the production of electroplated nickel silver (E.P.N.S.) luxury and table-ware, e.g. tea sets, flower vases, perfumery cases, butter dishes, *gulab pash, changer, khasdan, aftaba*, spoons, and forks. Articles are also imported into Moradabad from other towns, nickel plated, and marketed as Moradabad white metal ware. Electroplating with copper, zinc, cadmium, and brass is also carried out in India. Railway fittings are copper plated, refrigerator and machine parts are zinc plated, and aircraft and naval fittings are cadmium plated to impart resistance against saline corrosion. Bronzing, silvering, and copper oxidizing are mainly done for fancy electrical fittings. Gold plating is mostly done on jewellery, presentation articles, and for the manufacture of gold thread.



Indian Telephone Industries Ltd., Bangalore

FIG. 81—A PLATING SHOP

TABLE 4—PLATING CHEMICALS IMPORTED INTO INDIA

| Metal | Plating chemical | Trade name |
|----------|--------------------------|---|
| Copper | Copper cyanide (single) | Copper pink salt, Kuprit |
| | Copper cyanide (double) | Zonax copper salt, Rochelle copper salt |
| Nickel | Nickel sulphate | Albo nickel salt, Minerva nickel salt |
| | Nickel ammonium sulphate | Nivo nickel salt, Blacknic salt |
| | Nickel chloride | Zonax double nickel salt, Britenick salt |
| | Nickel carbonate | Hardnick salt |
| Chromium | Chromic acid | Chromax chrome salt, Zonax bright chrome salt, Silva-chrome, Hardchrome |
| Brass | Copper cyanide | Zonax brass salt, Brassit |
| | Zinc cyanide | |
| Silver | Silver nitrate | Zonax silver salt, Argentum |
| | Silver cyanide | |
| Cadmium | Cadmium cyanide | Zonax cadmium salt, Cadmas, Cadmium bright dip |
| | Cadmium oxide | |
| Tin | Sodium stannate | Stannic tin salt, Sodium stannate solution, Artax tin salt, |
| | Stannous sulphate | Acid tin solution, Tinnit tin salt |
| Zinc | Zinc sulphate | Galvanax zinc salt, Zincus salt |
| | Zinc cyanide | Zonax zinc salt, Brizine salt |
| Lead | Lead fluoborate | Zonax lead solution, Lead fluoborate solution |
| | Lead perchlorate | |
| | Lead acetate | |

The Indian Telephone Industries Ltd., Bangalore have facilities for copper, nickel, zinc, chromium, and cadmium plating.

The electroplating industry made good progress during World War II. Hard chrome plating of steel components was introduced. It has found application in the textile industry and for the renovation of worn out parts like spindles and dies. Anodizing of aluminium and its alloys was taken up and a beginning was made in the production of plating chemicals, such as copper salts, chromic acid, tin anodes, copper anodes, and anti-monial lead anodes. The establishment of factories for the manufacture of automobiles, aircraft, cycles, telephones, electrical appliances, and radio receivers has opened out vast possibilities for the development of the Indian electroplating industry.

Electroplating chemicals, chemical cleansers, and metal anodes are imported, mainly from U.K., indigenous production being inadequate. Small amounts of chromic acid, chrome salts, nickel salts, zinc salts, and copper salts are manufactured by the Phoenix Chemical Works, Bombay. Table 4 lists the chemicals imported for various plating baths.

Imports—Table 5 gives imports of electroplated ware into India.

Motor generator sets (6 volts, 100–1,200 amps.) are imported. Polishing lathes are available from local manufacture. Steel, wooden, and enamelled tanks are made locally. Only special types, particularly those required in automatic plating, are imported. Lustre Tripoli Powder, polishing compositions, and bronzing solutions are mostly imported.

TABLE 5—IMPORTS OF ELECTROPLATED WARE*

| | Val. (Rs.) |
|-----------------------|---------------|
| 1934/35–1938/39 (av.) | 226,545 |
| 1939/40–1943/44 (av.) | 119,453 |
| 1944–45 | 4,888 |
| 1945–46 | 54,311 |
| 1946–47 | 296,724 |
| 1947–48 | 291,441 |
| 1948–49 | 48,059 |
| 1949–50 | 101,044 |
| 1950–51 | 12,216 |
| 1951–52 | 37,260 |
| 1952–53 | 13,140 |

* Inclusive of plated ware and plated cutlery imported as baggage

India imported from U.K. 1,375 cwt. (val., £61,637) of cadmium compounds, including plating salts in 1946. Import of nickel salts in the same year was 3,205 cwt. (£12,946).

EMBROIDERY

Embroidery as ornamentation for woven fabrics has been known in India since ancient times. In the early stages the work was executed in gold and silver threads on silk fabrics. *Chikan* work on cotton came later. Indian embroidery today has been greatly moulded by Persian and other influences and practically all known types of this art are found in India in some form or other.

The outstanding embroideries of India are *kasida* of Kashmir, *phulkari* of Punjab and Rajputana, *kanbi* of Kutch, *kasuti* of Karnatak, and *chikan*

EMBROIDERY

of Uttar Pradesh. The influence of Baluchistan embroidery is perceptible in the *phulkari* of Punjab. The embroideries of Kutch and Kathiawar resemble the interlaced stitch of Spain and Germany. The *chikan* work of Uttar Pradesh is closely related to the washable linen embroidery of Europe, and the *kasuti* of Karnatak resembles the embroidery of Austria, Hungary, Spain, and the Slav countries.

A variety of materials has been employed for embroidery in India. Leather, velvet, meshed fabrics, and silk are used as base for cotton, woollen, silk, silver and gold threads. Beads and pieces of mirrored glass are employed for enhancing the decorative effects; even the enamel-like, shiny wings of beetles are reported to have been used for adding beauty to embroidered motifs. The methods of applique, couching, and quilting work have been utilized for producing a variety of effects.

Stitches—The main stitches employed in embroidery work are tacking stitch, chain stitch, buttonhole stitch, blanket stitch, herring-bone stitch, cross stitch, and hem stitch. The tacking stitch is the simplest. It includes running stitch, whipped-run stitch, Holbein stitch, pattern design, and surface darning. The chain stitch, including heavy chain and broad chain stitches, gives a more compact effect and is employed mostly in bead work. Split chain gives a light and delicate effect and wrapped chain and back chain stitches are useful for borders. Buttonhole and blanket stitches are used in cut work. The blanket stitch is used also for finishing edges and the buttonhole stitch for scalloping. The herring-bone stitch group includes chevron, interlacing, and single and double feather stitches. The cross stitch is used for bright colours and the hem stitch for work in which one set of threads, the warp or the weft, has been drawn.

Other stitches employed are the stem stitch and satin stitch, French knots, lazy daisy stitch, and Pekinese stitch. French knots are used wherever light, effective, raised decoration is desired. Bullion stitch, which is a variation of the French knot, is used with gold or silver thread to give a raised effect. The lazy daisy stitch is useful in working floral designs. The Pekinese stitch is used in Chinese embroidery for imparting graded effects.

Kasida embroidery was introduced into Kashmir in the middle of the fifteenth century by Persian artisans. It is worked on various kinds of silk and woollen fabrics including shawls, saries, and children's clothes, cushion covers, and handkerchiefs. The colours are rich, and the designs are elaborately executed. The patterns display the charm of free hand drawing and composition. The characteristics of Persian design, such as symmetry in composition, elegance, and poise and the

influence of Chinese art are discernible. The dominant motifs are flowers, foliage, butterflies, and birds. The stitches employed are the satin, the stem, and the chain stitches; the herring-bone and the darning stitches are occasionally used. The finest *kasida*, particularly on shawls and saries, has no 'wrong' side.

The beautiful *kasida* embroidery of Kashmir is world renowned. It is a flourishing cottage industry in Srinagar and neighbouring areas. About 55,000 workers are engaged in this work, a large number of them in embroidering *namda* (rugs) and *gabba* carpets (q.v.). The chain stitch is employed in embroidering *namda* using stereotyped designs. Embroidered *namdas* are produced in quantity and exported to U.S.A. *Gabba* is executed in applique, tattered woollens being sewn to the base with the chain stitch.

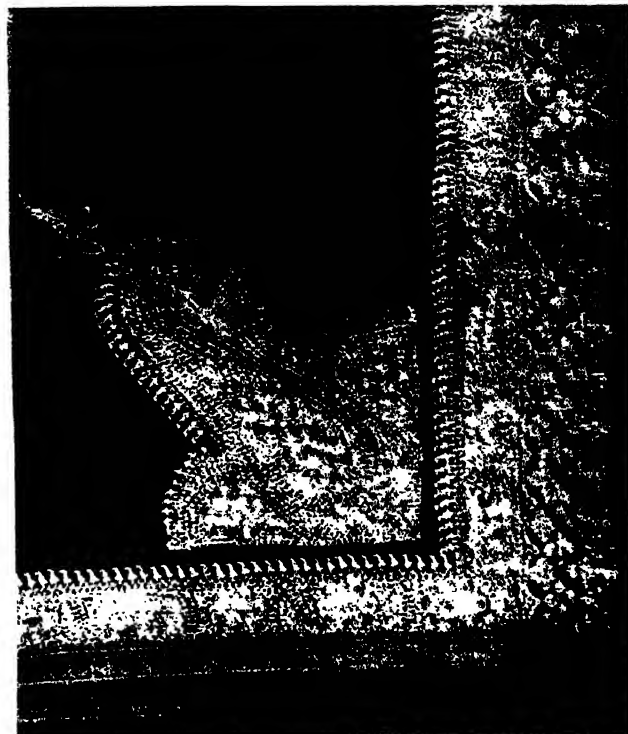
Another type of embroidery extant in Kashmir is *rafugari* usually worked on scarves and shawls, such as *pashmina*, taffeta, *shatush*, and *alwan*. The designs are worked evenly on both sides, and the price of an embroidered *pashmina* shawl may be



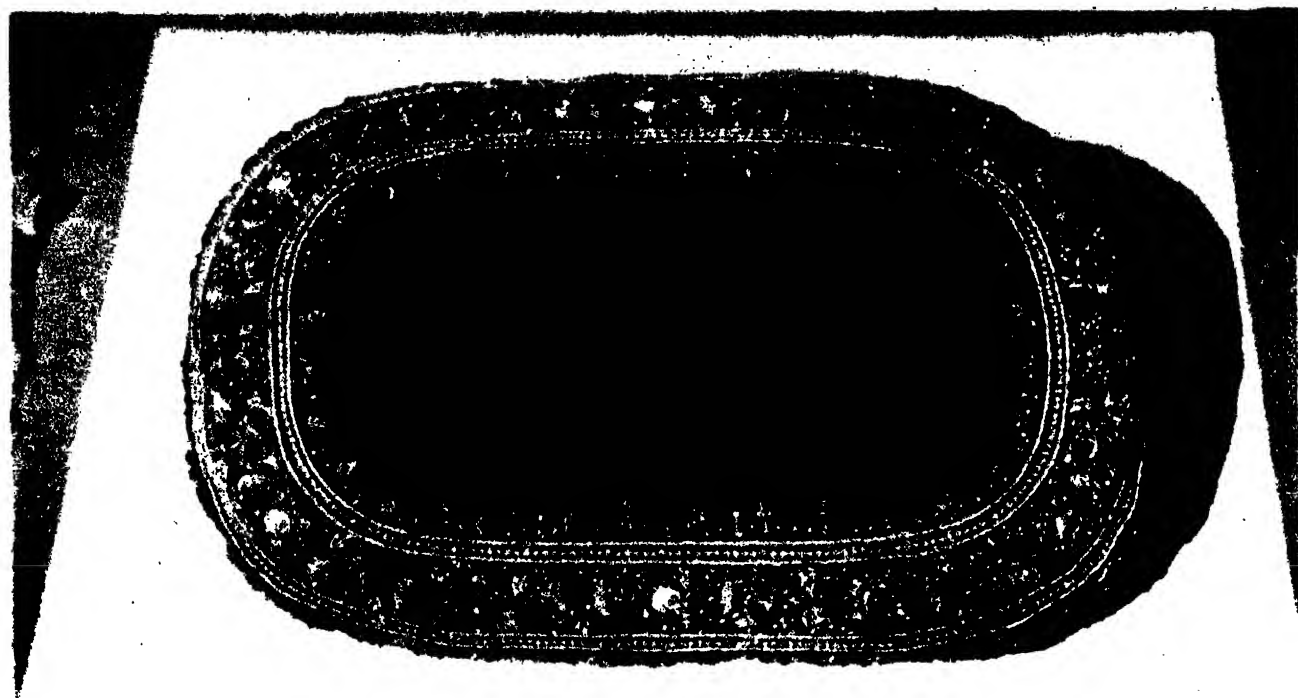
FIG. 82—EMBROIDERED KASHMIR SHAWL



Kashmir shawl embroidered in silk



Kashmir shawl embroidered in gold thread



Zardozi embroidered cushion

Jagat Narain & Sons Jewellers New Delhi

as high as a thousand rupees. Patterns on borders are sometimes produced on loom and sewn to the shawl later. Embroidered shawls are produced in Amritsar (Punjab) also, but the products are reported to be inferior to those of Kashmir.

Hessian with floral motifs and designs, embroidered in chain stitch using coarse wool, is used for making bags, screens, and cushion covers. All embroidered articles of wool, silk, hessian, and cotton find a ready market in India and abroad.

The *phulkari* of Punjab is well known in Europe. The chief centres of the embroidery are Rohtak, Hissar, Gurgaon, and Karnal.

Phulkari is executed in darning stitch on coarse khaddar-like cloth of red or blue colour in diapers of floral designs. The design is worked from the reverse side of the cloth with strands of untwisted silk, producing an effect of tapestry with silken sheen. In well executed specimens the base is fully covered and the fabric is indistinguishable from the embroidery.

Bagh (garden) and *chobe* are varieties of *phulkari*. The whole surface of the fabric is ornamented in the *bagh* using as motifs *Shalimar bagh*, *kakri bagh*, *mircha bagh*, and *dhunia bagh*. *Chobe* is executed on the edges of the cloth to produce border-like effects.

Elaborate and gorgeous embroidery, executed in chain stitch with a hook-like crochet needle, known as *kanbi*, is characteristic of Kutch, Kathiawar, and Sind. The fabric is kept taut in a wooden frame and probed by a hook-like crochet needle, the thread being introduced from beneath. The motifs used are elephants, canopies, fans, peacocks, and parrots. Sometimes small pieces of mirror glass are introduced into the design and bound down by stitching round them. Borders are sometimes embroidered in laid stitch, couching, and herring-bone stitch. Coloured thread may be introduced to indicate the veins, the stems, and the various tints in the motifs.

A speciality of Kathiawar embroidery is the introduction of small mirrors in the designs. Embroidered pieces are particularly valued for *cholis*, *nottis*, *choklas*, *torans*, and *ghaaras*. Darning, herring-bone, interlaced, and chain stitches are employed. The base is sometimes composed of several strips sewn together to form panels (Dongerkerly, 32).

Kasuti embroidery is executed in the Karnatak districts of Dharwar, Bijapur, and Belgaum and in the neighbouring areas of Jath, Sangli, Miraj, and Jamkhandi. Many *kasuti* designs have been reproduced on handloom, the bodice pieces so embroidered being known as *ilkal khanns*.

Kasuti is executed on hand woven cloth of dark colour, ordinarily black, with silk thread in line and back stitch, running stitch (straight or zig-zag), and cross stitch. The designs favoured are temples, the *tulsi* plant (*Ocimum sanctum*),

sacred bull, elephant with howdah, peacocks, parrots, etc. Floral motifs are also common. The embroidery is multi-coloured with a harmonious blending. The usual colour combinations are red, green, orange, and purple, or crimson, green, and orange (Dongerkerly, 35).

Chikan embroidery on white or cream cotton or muslin has reached a high degree of excellence in Lucknow. Other centres of this art are Agra, Kanpur, Allahabad, Banaras, Delhi, Patna, and Gaya. The designs, mostly floral, without any colour scheme are printed from a wood block in a colour that can be easily washed out. The work is best liked on muslin, but it is also done on cambric and georgette. Coloured yarns and coloured fabrics have since been introduced and are becoming increasingly popular. The work is done on *Dupalli topees*, blouses, frocks, saris, *dupattas*, handkerchiefs, curtains, table covers, tray covers, napkins, dollies, tea cosies, etc.

Chikan work comes closest to linen embroidery and lace work of the West. The stitches employed are the satin stitch, the stem stitch, the back stitch, the herring-bone stitch, and the buttonhole stitch. The designs are borrowed from grains, flowers, and leaves. The most intricate design is the *bukhia*, in which the stitches cover the back of the cloth in the style of the herring-bone stitch, producing an opaque effect on the surface of the fabric; the outlines of the design are executed with minute stitches resembling the strokes of the back stitch. *Khalao* is a form of applique work in which the same fabric is used to produce opacity and the ordinary stitch for the outline. Both *bukhia* and *khalao* embroidery belong to the category known as 'flat' embroidery.

An 'embossed' variant of *chikan* work is the *murri* or *phanda* characterized by raised knots. The net or *jali* embroidery is produced by the needle, the strands of the fabric being drawn aside by a form of buttonholing to suit the pattern. Various types of *jali*, e.g. *Madras jali* and *Calcutta jali*, some of them intricate, are produced.

Chikan embroidery is practised as a cottage industry and in the recent past was monopolised by a few traders. There are about a thousand skilled workers in Lucknow and an equal number in the neighbouring villages of Malihabad, Itaunja, Kursi, Sandila, and Kakori. The work executed by village artisans is usually coarse; it is finished at Lucknow before marketing.

A scheme for the development of the *chikan* embroidery industry has been introduced by the Government of Uttar Pradesh. Under this scheme the cloth is procured through the control authorities, cut or sewn according to requirements, designs to suit varied tastes are printed on the pieces, and the pieces distributed to cottage workers through supervisors with the wages for

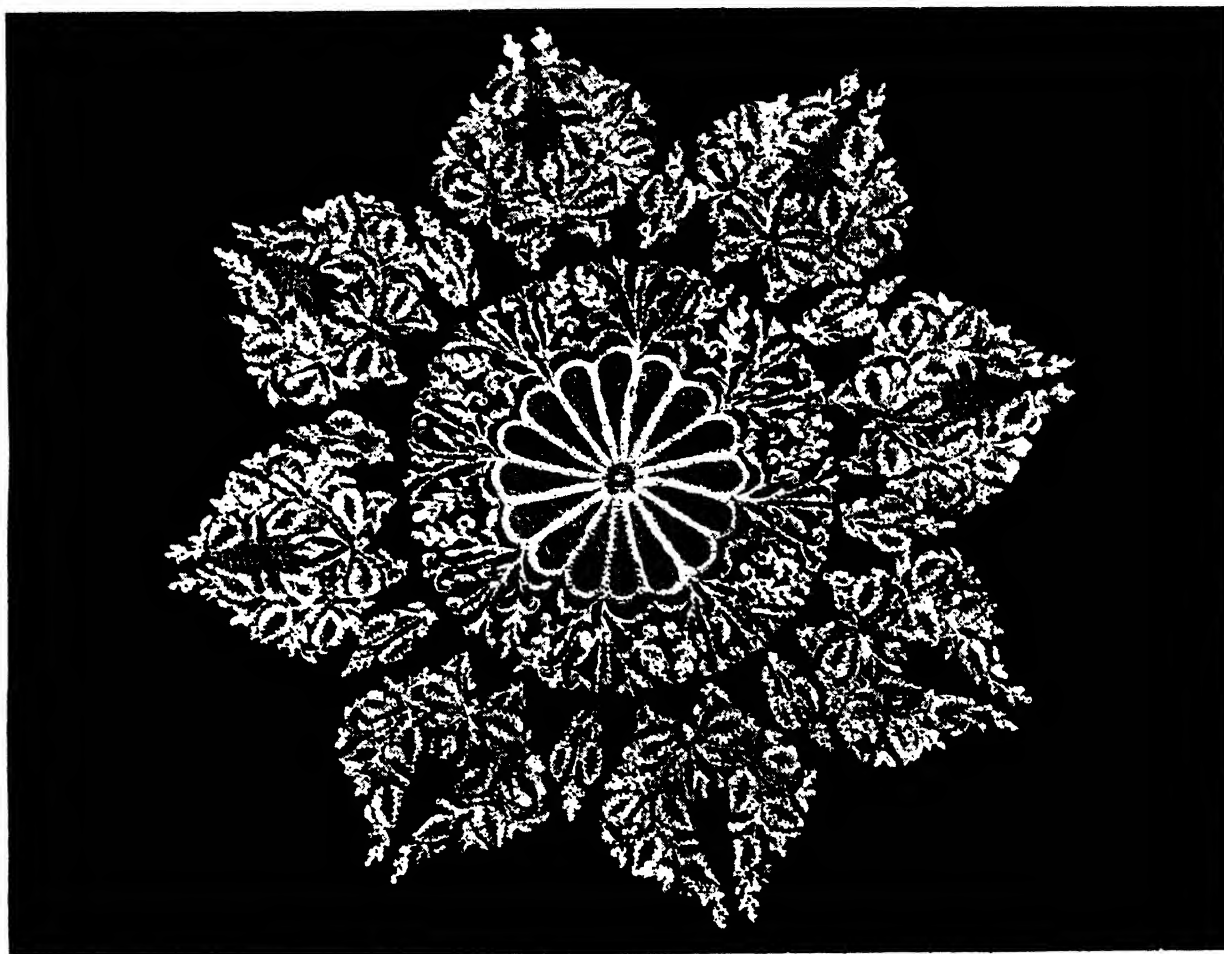


FIG. 83—CHIKAN WORK

the work printed on the pieces. Finished pieces are collected by women supervisors, washed and marketed under government auspices. The number of workers under this scheme in 1947-48, when the scheme was introduced, was 250; in 1951-52, the number was 630. During this period, 228 new designs were introduced and embroidered pieces worth Rs. 3,36,000 were produced and Rs. 1,93,000 paid to workers as wages. In 1952-53, goods worth about Rs. 1,50,000 were produced and two-thirds of it was paid to workers as wages.

There is a large demand for *chikan* goods in India, Pakistan, Ceylon, U.S.A., and U.K. (*Development of Industries in the Uttar Pradesh*, 1950-51, 110).

Gold and silver embroidery—Among the numerous varieties of Indian embroidery, the oldest is perhaps the gold and silver embroidery. The important producing centres are Surat, Banaras, Delhi, and Lucknow.

Gold and silver embroidery is executed with a

variety of tinsels, such as *salma*, *ghizai*, *sitara*, *kamdani*, and *kalabatun*. *Salma* is coiled wire produced by twisting flattened or round wire round a needle. A variety of types, *tikora salma* (flattened wire, 300-400 yd./tola twisted round a five-sided needle), *dabkahua salma* (twisted round a fine needle), *kora salma* (round wire twisted closely over a thick needle), and *motiya salma* (round wire wound closely over a thin needle), are known in the trade. *Ghizai* is made by passing a flattened wire through an eyelet to give a convex shape on one side and a concave shape on the other; it is then twisted round a fine needle so that the convex side is on the outside. *Sitara* or spangles are made from a wire (c. 16 yd./tola) by winding it round a needle, c. 1/16 in. diam., and then cutting it longitudinally to produce rings which are subsequently flattened over an anvil. *Kamdani* or *mukaish* is a flattened wire of c. 24 S.W.G. *Gokharu* is a spiral of flattened wire. *Kalabatun* or *kasab* is finely drawn wire

(600–700 yd./tola) flattened and twisted round a silk thread; a combination of four or more threads twisted or plaited together is known as *dori*.

Light embroidery in gold and silver threads on fine fabrics, known as *kamdani*, is executed with *mukaish* wire using the darning needle and the conventional patterns of flowers and stars. The worked design is beaten from the reverse side so that both sides look alike. The work carried out by Lucknow artisans excels that produced in Delhi and elsewhere.

Zardozi is the name given to heavy embroidery on silk fabric in raised gold thread. The fabric is stretched in a frame and the design traced. *Salma*, *sitara*, *kalabatun*, and *badla* are sewn or tacked with silk according to the design.

Exquisite *zardozi* embroidery is carried out with *kalabatun* on shawls and saris. The designs are often complicated. In Kashmir and Amritsar, *ari* work is executed with a crochet hook with *kalabatun* in chain stitch. A machine with a direction control has been designed for this work. Leaves and petals are done in *vashi* work, the *kalabatun* being tacked in close parallel lines to cover the design completely.

Fine and elegant designs are used for *zardozi* work on caps, skirts, and borders. Bold designs

on velvet are used for elephant trappings, palanquin canopies and the like. Portions of the design may be cushioned by sewing with woollen thread or inserting cardboard pieces. Petals and leaves are worked with *salma* and the centres with spangles. *Ghizai* is stitched on the outlines and stems. Small leaves are made by fixing pieces of *kora* or *dabkahua salma*. *Tikora salma* is mostly used for flowers and leaves. Sometimes, as in *mina* work, portions are embroidered in coloured silk and the rest worked with tinsel. After working up the design, the reverse side is glued and loose thread ends are stuck.

Twisted *dori* is employed in *jali* and *buti* work on saris. Excellent work with *kalabatun* is carried out in Lucknow on georgette and tissue saris. Borders are seldom embroidered but ready-made *Banarsi* or *Zardozi* borders are stitched on. Sometimes *jali* (distant flowers connected to each other by long curved stems) is embroidered on sari ground.

Hand bags are embroidered on velvet with *salma*, *sitara*, and *ghizai*. The designs are generally flowers, monuments, or birds. Sometimes precious stones are used. Garlands for ceremonial use are made from cardboard covered with embroidered coloured fabrics. Cardboard pieces covered with elegantly embroidered cloth are also

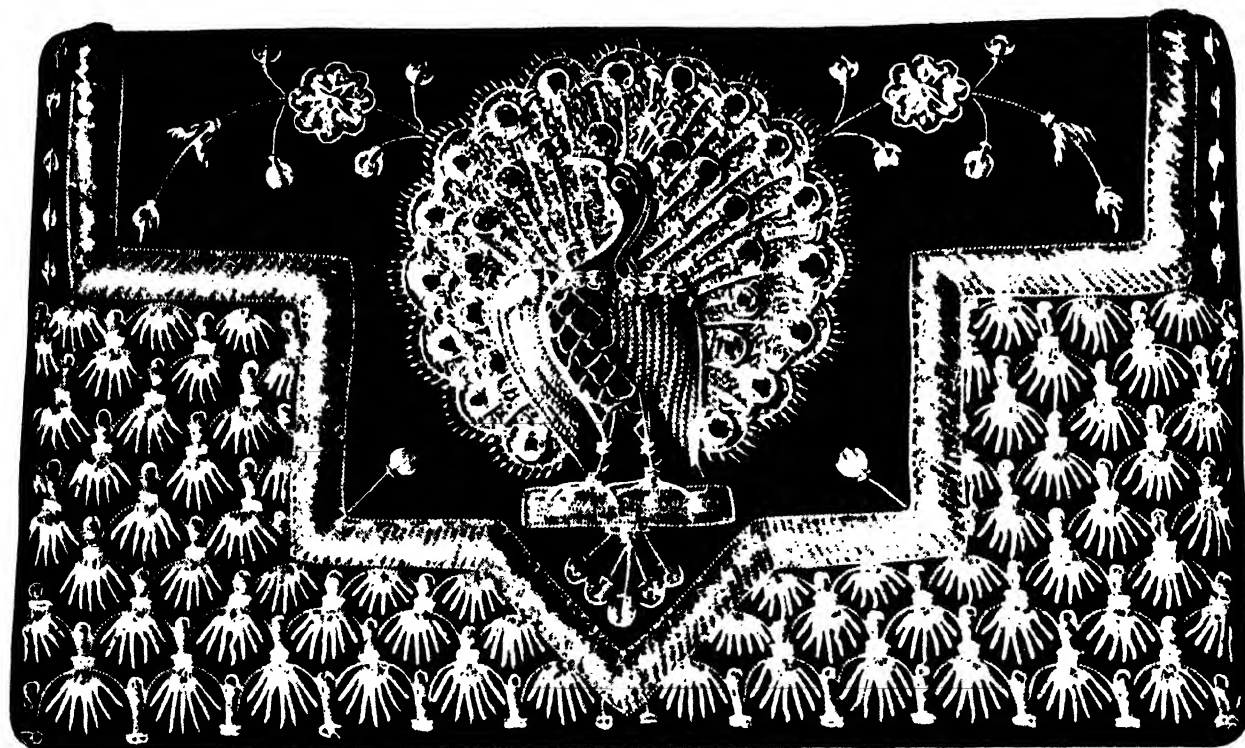


FIG. 84—ZARI WORK ON VELVET BAG

EMBROIDERY

used for making head dresses and ornaments for use on the stage.

ENAMELWARE

Enamel is the glass-like opaque or semi-transparent coating applied to metallic surfaces for protection or ornament. The term vitreous or porcelain enamel is usually employed for such coating in order to distinguish it from glossy paint, which is also sometimes called enamel.

Enamelled iron ware finds varied uses in households and industry. Articles of domestic use include cooking utensils, sanitary ware (bath and wash tubs, sinks), refrigerators, and water heaters. Enamelled storage tanks, cooking kettles, vacuum pans, and digesters are used in chemical, pharmaceutical, food, and dairy industries. Porcelain enamelling is also used extensively in hospital furniture. Enamel is also applied as decorative cover for advertising signs, table tops, etc. Coated articles are weather-proof, acid- and stain-resisting, and durable. They are superior to lacquered ware as regards abrasion resistance, durability, and thermal resistance.

Jewellery enamels cover a specialized field of art enamelling.

Raw materials

The raw materials used in the enamelling industry may be considered under two broad groups—chemicals and metal stock.

Chemicals—The chemicals employed may be considered under refractories, fluxes, opacifiers, colours, electrolytes, and floating agents. Refractory materials—quartz, felspar, clay, and rutile—contribute the acidic part of the melt and give body to the enamel. Fluxes—borax, soda ash, soda nitre, fluorspar, cryolite, whiting, barium and magnesium carbonates, litharge, red lead, and zinc oxide—react with the refractories to form glass; fluxes also lower the fusion temperature. Opacifiers—oxides of tin, antimony, zirconium, and titanium, sodium antimonate—impart to the glass the appearance characteristic of vitreous enamels. Oxides of cobalt, copper, iron, and nickel are used as colourants. Borax, soda ash, magnesium carbonate, and magnesium sulphate are employed for deflocculating clay, keeping the enamel in suspension, and controlling the pH. Floating agents—clay, gum tragacanth, gum arabic, ammonium alginate, and bentonite—are mill additions for keeping the enamel suspended in water or in some other medium (Andrews, 11).

Metal stock—Sheet steel, cast iron, and occasionally sheet iron form the base metal for enamelling. Table 1 gives the composition of enamelling irons.

Titanium steel has been recently introduced as a base metal for vitreous enamel. Low carbon

TABLE 1—COMPOSITION OF SOME ENAMELLING IRONS*

| | | Enamelling iron e.g. | | |
|------------------|---|----------------------|--------|-----------|
| | | Mild steel | Armco | Cast iron |
| Total carbon, | % | 0.05-0.13 | 0.013 | 3.25-3.60 |
| Graphite-carbon, | % | .. | .. | 2.80-3.20 |
| Silicon, | % | trace | trace | 2.25-3.00 |
| Manganese, | % | 0.30-0.45 | 0.023 | 0.45-0.65 |
| Phosphorus, | % | 0.05 (max.) | 0.0075 | 0.60-0.95 |
| Phosphorus, | % | 0.04 (max.) | 0.02 | 0.05-0.10 |

* *Vitreous Enamels*, Borax Consolidated Ltd., London, 1949, 16

steel containing sufficient titanium to combine with all the carbon present, can be enamelled satisfactorily without the use of a ground coat. The titanium content should be more than 4.5 times the carbon content in order to avoid blistering. Titanium steel has superior enamelling properties, excellent deep drawing qualities, and is more resistant to sagging at enamelling temperatures than the usual types of sheet metal. It has, however, a low yield strength at room temperature, but varieties containing manganese, nickel, and copper combine high strength and good enamelling property (Borax Consolidated Ltd., *Vitreous Enamels*, 1949, 17).

Iron sheets of 31 gauge stock are used for kitchen ware; for larger sizes, sheets of 24-28 gauge are required. Sheets of 20-24 gauge are used for stove parts, and of 18-20 gauge for table tops, refrigerator linings, and signs. Heavy ware used in chemical and food industries are made of 4-10 gauge stock. Sheets should have a smooth, velvety (not spongy), but firm and fine-grained surface (Andrews, 72).

Preparation of metal surface

The quality of finished enamelware depends on the surface characteristics of the metal stock. The surfaces of foundry castings are usually covered by scale and sand. They should be freed from all traces of dirt, grease, rust, and scale and roughened to ensure good adhesion of the enamel coat. Cast iron surfaces are cleaned by sand-blasting or shot-blasting after annealing. The treatment for sheet metal surfaces varies with the ware. Sheet iron articles of heavy gauge are cleaned in the same way as cast iron articles by shot-blasting after annealing to release stresses. Lighter gauge sheets are cleaned by pickling.

Degreasing may be effected by heating the ware to dull red heat (600-650°). This method has been almost completely replaced by solvent cleaning using trichloroethylene followed by hot dilute alkali solution. Cleaning solutions contain: caustic soda, 15-35; soap, 5-12; trisodium phosphate, 10-30; sodium metasilicate, 10-40; and soda ash, 10-30%.

Borax is sometimes added to improve the deflocculating and emulsifying properties of cleaning solutions. Degreased articles are washed with hot water and pickled to remove the scale. A pickling bath of 10–12% solution of hydrochloric acid is usually employed in U.K. A 6–8% solution of sulphuric acid at 60–70° is preferred to hydrochloric acid in U.S.A. A solution containing c. 10% sulphuric acid and 1–5% hydrochloric acid has been suggested. Pickled articles are rinsed in hot water. Acid pickling produces an etched face which gives a strong bond between the iron and the ground-coat enamel.

Pickled ware may be nickel plated before enamelling. For nickel deposition a bath containing nickel sulphate ($\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$), 1–2 oz.; boric acid or nickel ammonium sulphate, 0.25 oz.; and water to 1 gallon is employed. Plating is carried out at 65–80° and at pH, 5.8–6.2; higher acidities may also be employed. Nickel-dipped ware is rinsed with water and neutralized in a bath containing soda followed by treatment with a weak solution of sodium nitrite (not exceeding 0.5%) for rust inhibition. Neutralizing baths containing borax or sodium cyanide may also be used. After thorough rinsing, the ware is quickly dried to prevent rusting.

Preparation of enamel

The 'frit' is prepared by fusing a mixture containing refractory materials and fluxes, e.g. feldspar, borax, soda ash, silicon, fluorspar, cryolite, sodium nitrate, and lime. The fused mass is quenched in water and broken into pieces. Frit is employed along with 'mill addition' for enamelling.

Two types of enamel are in use: dry process enamel and wet process enamel. The former is applied in powder form after dry grinding with opacifiers or colouring agents. Dry process enamels may be leadless or lead-bearing, acid-resisting or non-acid-resisting. Wet process enamels are applied in slip form. The frit is ground with water to a slip in a pebble mill along with floating agents (such as clay), opacifiers (usually oxides of tin, zirconium, or antimony) or colouring oxides. The mill additions do not normally exceed 15% of the weight of the frit.

A clear frit is required for coloured enamels. Colour and opacity are imparted by mill additions. Dark blue and black enamels are prepared by melting the frit along with the colourants.

Enamelling

Enamelling operations vary according to the type of enamel employed. The dry process is commonly employed for enamelling heavy cast iron articles. A ground coat is first applied by the wet process. The article is heated to a point above the fusion point of the enamel and dusted

with dry powder when it melts and forms a continuous coating. On refiring a smooth porcelain surface is obtained. Smaller articles are heated and dipped in the powder; the enamel clings to the surface, melts, and forms a smooth coating. The process is repeated until the required thickness is built up. Blisters, which may occur during heating, are punctured and the surface re-dusted.

The wet process is employed for enamelling sheet metal ware. The ware is given a ground coat followed by one or more cover coats. The article is fired after each coat, but sometimes the cover coat is applied over the unfired ground coat and both coats fired in one operation. The cover coat is sometimes applied directly to the base metal. Where appearance is not important, the ware is finished with the ground coat.

The enamel is applied by dipping or spraying. The ground coat is usually applied by dipping the article in the prepared slip. The excess of slip is drained into the dipping tank. The thickness and the uniformity of coating are determined by the water content of the slip. On firing, the ground should have a thickness of 0.002–0.005 in. A second coat may be applied by spraying if required.

The cover coat may also be applied by dipping using fine-milled enamel with relatively low sp.gr. A very thin cover coat is obtained by this method. The more common method of applying the cover coat is spraying. In electrostatic spraying, the positively charged object is surrounded by an electrode system conforming to it in contour. 'Atomized' enamel particles entering the electric field are given a negative charge and are deposited on the surface of the article (Willis, *J. Amer. ceram. Soc.*, 1945, 28, 121).

After applying the enamel, the article is dried in a cabinet or conveyor drier heated by gas burners, steam, or waste heat. Heating by infra-red lamps is particularly suitable for flat surfaces. Dried articles are fired in box muffle furnaces fired by coal, oil, or gas, or heated by electricity. The ware is supported on heat-resisting 'perrits' made of a special alloy of iron, nickel, and chromium (Phelan, *Proc. Porcel. Enam. Inst.*, Fifth Annual Forum, 1940, 75).

Continuous furnaces are employed for mass production, especially of hollow ware and stove and refrigerator components. They are of two types, viz. overhead conveyor furnaces and roller-hearth furnaces. The former may be straight or U-shaped, the latter being more common. The ware, carried from an overhead mono-rail conveyor, travels through a pre-heating zone into the firing chamber, and then through a cooling zone before emerging out of the tunnel. Waste heat from the outgoing ware is utilized for pre-heating.

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The roller-hearth furnace consists of a long straight tunnel through which the ware travels on a series of transverse rollers, first through a pre-heating zone, then through the hot zone heated by metallic radiant tubes, and lastly through a cooling zone. An automatic device is provided for returning the perrit bars to the loading end of the furnace.

Satisfactory and consistent enamel finishes can be secured by maintaining uniform operating conditions. The temperatures at which enamels are fired vary between c. 700° and 920° according to type. Table 2 gives the temperature and fusion times for box muffle operation using lead-free enamels.

Gaseous products, especially water vapour and sulphur dioxide, should not be allowed to come into contact with the ware during firing. Water vapour in concentrations exceeding 3% imparts a roughened singed appearance to ground-coat enamels and cover coats applied over them are blistered and defective. Even when present in amounts less than 3%, water vapour causes blistering and boiling in cover coat enamels, although no such defects are visible in the ground coat.

Combustion products in the furnace atmosphere may also give rise to 'copper-heading' in sheet iron ground coats and to scumming troubles in cover coats, particularly in dark coloured coats. Black enamelled ware is liable to develop a whitish appearance when stored under humid conditions due to the deposition of alkali sulphate. Acid-resisting enamels are particularly prone to such defects when fired in an atmosphere containing sulphur dioxide.

Enamelware is often decorated by screening, decalcomania, printing, graining, marblizing, stepping, polytone, or by photography and hand decoration.

Enamel composition

The ground coat ensures adherence of the enamel and prevents any chemical action between the metal base and the ingredients of the cover coat. A ground coat should have workability, i.e.

TABLE 2—FUSION TIMES AND TEMPERATURES FOR LEAD-FREE ENAMELS*

| | Time (min.) | Temp. (°C.) |
|------------------------|----------------|----------------|
| Sheet iron ground coat | 2-8 | 830-900 |
| Sheet iron cover coat | 2-7 | 750-830 |
| Cast iron ground coat | 15-30 | 800-840 |
| Cast iron cover coat | 15-30 | 740-820 |

Vitreous Enamels, 1949, 30

Lithium containing frits, used for sheet iron ground coat, fuse at 700-750°

freedom from processing troubles. Blends of two or more frits with low fusion points, selected on the basis of their coefficients of expansion, thermal shock resistance, impact resistance, adherence to metal stock, and resistance to chipping and formation of hairlines are generally used for ground coats (*Proc. Porcel. Enam. Inst., Ninth Annual Forum, 1947, 10*).

The cover coat imparts a good appearance and provides a surface resistant to acids, alkalis, atmospheric corrosion, soil corrosion, hot water, thermal shock, scratching and abrasion, high temperature, crazing, and abrasion. Antimony-opacified frits, both non-acid-resisting and acid-resisting, are widely used. They give high reflectance at low weights of application. Zircon-containing frits are not acid-resisting, but give more opaque coatings with lower weights of application as compared to antimony-opacified frits; they cannot be used for kitchen utensils. The enamelled surface may be glossy, matte, or semi-matte (*Proc. Porcel. Enam. Inst., Ninth Annual Forum, 1947, 12*).

Sheet iron ground coat—Quartz (c. 65%), feldspar, and borax (10-30%) form the principal constituents of ground coat enamel. The ratio of quartz to feldspar determines the working properties. The alkali oxide (Na_2O) content is kept at 18-22% and that of fluorspar at 3-7%. The latter lowers the viscosity of the enamel at temperatures above the fusion point. Excess of fluorspar causes blistering or pinholing. Nickel and manganese oxides are commonly used with cobalt oxide for colouring enamel. Copper and iron oxides are used for imparting dark colours. Table 3 gives the composition of typical ground coats used for different purposes.

Sheet iron cover coat—The cover coat enamel should have a lower fusion point than the ground coat, but for good adherence, the softening point of the latter must lie within the fusion range of the cover coat.

Cover coat enamels of light colour are opacified by oxides of tin and zirconium; sodium antimonate, cerium oxide, and titanium oxide are used occasionally with certain types of frits. Transparent colourless frits are required for enamels of bright colour, such as green, blue, red, and brown.

Non-acid-resisting enamels are similar to ground coat enamels in composition, but without cobalt oxide. Acid-resisting frits contain less of feldspar and more of silica; the alkali content is reduced and titanium oxide added.

Table 4 gives the composition of some sheet iron cover coats.

Cast iron enamel (Wet process)—Special ground coats, known as 'grip coats', are widely used for enamelling castings. A typical composition used for this purpose is the following: hydrated borax (30 lb.), ball clay (20 lb.), quartz (80 lb.), and

TABLE 3—COMPOSITION OF SHEET GROUND COATS*

| Enamel | SiO ₂ | Al ₂ O ₃ | B ₂ O ₃ | Na ₂ O | K ₂ O | CaO | CaF ₂ | CoO | NiO | MnO |
|------------------------------------|------------------|--------------------------------|-------------------------------|-------------------|------------------|-----|------------------|------|------|-----|
| Average sheet | 47.5 | 5.05 | 19.4 | 17.45 | 2.1 | .. | 5.3 | 0.5 | 1.2 | 1.5 |
| Kitchenware | 52.8 | 5.3 | 13.9 | 14.6 | 2.4 | .. | 7.4 | 0.6 | 0.9 | 2.1 |
| Cooking utensils (a : b - 60 : 40) | (a) 48.0 | 6.3 | 14.8 | 17.5 | 2.9 | 2.5 | 6.5 | 0.6 | 0.2 | 0.7 |
| | (b) 55.0 | 6.0 | 12.4 | 15.4 | 2.6 | 1.4 | 6.3 | 0.25 | 0.75 | .. |
| Heavy sheet | 51.5 | 6.4 | 17.5 | 16.5 | 2.8 | | 3.6 | 0.6 | 0.4 | 0.7 |
| Black ground coat | 44.2 | 4.8 | 17.5 | 16.0 | 2.1 | 2.2 | 5.4 | 2.4 | .. | 5.4 |

* Vitreous Enamels, 44

TABLE 4—COMPOSITION OF SHEET IRON COVER COATS*

| Enamel | SiO ₂ | Al ₂ O ₃ | B ₂ O ₃ | Na ₂ O | K ₂ O | CaF ₂ | Na ₂ AlF ₆ | ZnO | BaO | Sb ₂ O ₃ | Na ₂ SiF ₆ | TiO ₂ | CaO | CoO | MnO ₂ | CuO |
|----------------------------|------------------|--------------------------------|-------------------------------|-------------------|------------------|------------------|----------------------------------|-----|-----|--------------------------------|----------------------------------|------------------|-----|-----|------------------|-----|
| White for sheets | 42.2 | 6.1 | 14.1 | 10.5 | 2.7 | 3.3 | 10.3 | 2.0 | 0.8 | 8.0 | .. | | | | | |
| do. | 53.3 | 7.6 | 9.9 | 7.8 | 3.4 | | 18.0 | | | | | | | | | |
| White for kitchenware | 45.0 | 9.6 | 10.5 | 9.8 | 2.2 | | | | | | 22.9 | | | | | |
| Frit for signs | 47.5 | 7.1 | 16.7 | 13.6 | 3.2 | 4.3 | 7.6 | | | | | | | | | |
| White for cooking utensils | 56.0 | 5.3 | 7.0 | 8.7 | 2.4 | 3.8 | 14.6 | | | | | 2.2 | | | | |
| A. R. glaze | 50.0 | 4.6 | 12.0 | 11.8 | 2.0 | | 2.5 | | 6.0 | | | 7.6 | 3.5 | | | |
| Black cover coat | 48.0 | 5.0 | 16.5 | 14.0 | 2.2 | 9.2 | | | | | | | | 0.8 | 3.5 | 0.8 |

* Vitreous Enamels, 46

TABLE 5—COMPOSITION OF CAST IRON ENAMELS (WET PROCESS)*

| Enamel | SiO ₂ | Al ₂ O ₃ | B ₂ O ₃ | NaKO | CaO | Na ₂ AlF ₆ | Na ₂ SiF ₆ | CaF ₂ | Sb ₂ O ₃ | MgO | TiO ₂ | ZnO | BaO |
|------------------------------------|------------------|--------------------------------|-------------------------------|-------|------|----------------------------------|----------------------------------|------------------|--------------------------------|------|------------------|------|-----|
| White on groundcoat | 47.2 | 5.65 | 9.25 | 13.0 | 2.25 | 7.1 | 12.5 | 1.2 | 1.85 | .. | .. | .. | .. |
| White or colour on groundcoat | 47.0 | 3.4 | 19.7 | 12.87 | .. | 5.9 | .. | 3.42 | .. | 1.86 | 5.85 | .. | .. |
| White for direct application | 34.1 | 2.3 | 22.0 | 8.6 | | | | 9.5 | 3.0 | .. | .. | 11.5 | 9.0 |
| Colour frit for direct application | 31.3 | 5.3 | 23.7 | 15.7 | 2.5 | | | 8.8 | .. | .. | .. | 12.0 | 0.7 |

* Vitreous Enamels, 48

water (70 lb.). The ground coat enamel is applied by spraying and fired at 830°. Cover coat enamels for castings are similar to sheet iron frits in composition, but are somewhat more fusible. The borax content is kept high for improved workability. Table 5 gives the composition of wet process enamels for cast iron.

Cast iron enamel (Dry process)—Dry process enamels have low softening and fusion points. The opacity is generally developed in the frit. The composition varies according as the enamel is applied by dusting or by dipping. The enamel required for application by dipping should have low softening and melting temperatures so that

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TABLE 6—COMPOSITION OF CAST IRON ENAMELS (DRY PROCESS)*

| Enamel | SiO ₂ | Al ₂ O ₃ | NaKO | B ₂ O ₃ | Na ₂ AlF ₆ | CaF ₂ | ZnO | Sb ₂ O ₃ | BaO | CaO |
|-------------------------------|------------------|--------------------------------|-------|-------------------------------|----------------------------------|------------------|-------|--------------------------------|------|------|
| White for dusting | 33.90 | 5.30 | 17.20 | 14.80 | 2.50 | 5.00 | 11.20 | 10.10 | .. | .. |
| White for dusting | 33.70 | 5.15 | 14.95 | 16.20 | 4.10 | 5.10 | 10.20 | 8.20 | 2.40 | .. |
| White for dipping | 22.30 | 5.70 | 15.70 | 22.20 | 3.90 | 3.20 | 11.50 | 11.50 | 4.00 | .. |
| Resistant white for bath tubs | 34.20 | 4.16 | 14.00 | 18.36 | 5.08 | .. | 14.20 | 10.00 | .. | .. |
| White for sanitary ware | 35.00 | 5.80 | 16.50 | 15.70 | 2.00 | 3.00 | 9.40 | 7.00 | .. | 5.60 |

* Vitreous Enamels, 50

it sticks to the hot metal, the heat being sufficient to give a smooth glossy surface. A relatively large proportion of boric acid is employed to lower the softening point. Zinc oxide as fluxing material (5–10%) imparts good gloss and strength. Barium carbonate (5–6%) improves fusibility, gloss, and brilliance. Table 6 gives the composition of dry process enamels.

Dry enamels are applied over a ground coat. Enamels used for the ground coat are similar in composition to those used in the wet process and are applied by dipping, spraying, or brushing.

Testing

Tests for enamels include the following: (1) fusibility of dry unfired enamel, (2) thermal shock test of the finished piece, (3) measurement of reflectance, adherence, and acid resistance, and (4) trial burn at the firing temperature for the duration actually employed in practice (Andrews, 325).

Defects which are likely to develop in enamelware are blistering, boiling, burning-off, chipping, copper-heading, crawling (tearing), fish-scaling, orange peeling, reboiling, rust-spotting, scumming, shore-lining, and strain-lining.

THE INDIAN INDUSTRY

The comparatively high price of brass and copper has contributed to the increasing use of enamelled iron ware in Indian households. India annually imported enamelware worth about Rs. 20 lakhs before World War I. The manufacture of such ware was first undertaken on a commercial scale in 1922, when two factories, the *Sur Enamel & Stamping Works, Ltd.*, Calcutta and *Bengal Enamel Works Ltd.*, Palta (Dt. 24-Parganas) were established and production of domestic ware and sign plates was started. During the quinquennium following World War I there were 4 firms manufacturing enamelware.

In 1924 the Tariff Board reported that prospects for the growth of the enamelware industry in India were not unfavourable if initial difficulties

could be removed. The Board recommended that imports of chemicals, such as borax, cryolite, and cobalt oxide, required by the industry should be free of duty, a recommendation which was not accepted by the Government. World War II gave a fillip to the industry. The heavy demands of the Supply Department, hospitals, field ambulance services, etc. had to be met, and several new factories came into existence. There were 12 factories (Bengal, 2; Bombay, 5; Delhi, 1; Madras, 1; and Punjab, 3) in 1943 engaged mainly in the production of ware required for war purposes. There are at present 21 factories in the Indian Union with a capacity for producing 21,000,000 pieces of enamelware annually.

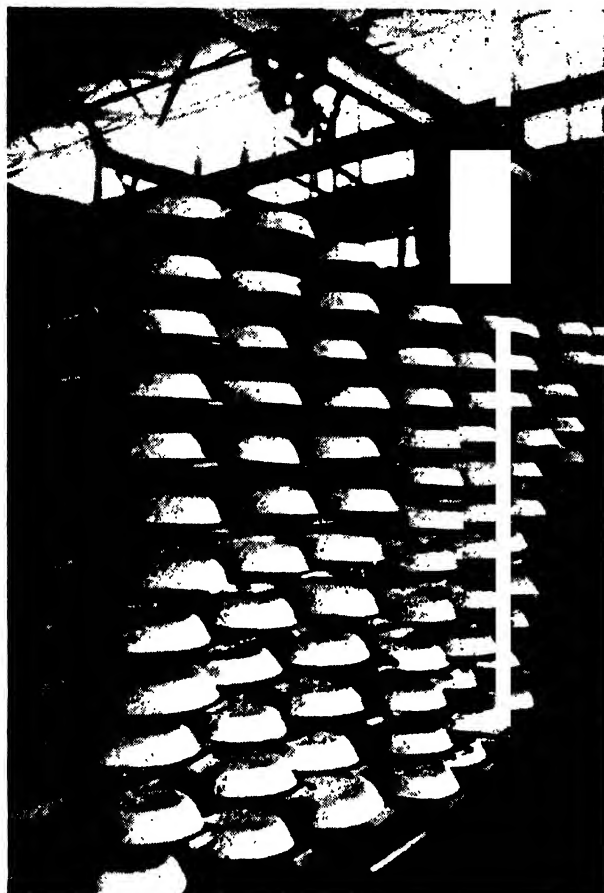
Sand, felspar, and clay, constituting nearly 60% of the bulk of enamels, are available in India. Borax, soda ash, cryolite, tin oxide, cobalt oxide, and a few other chemicals are imported.

Mild steel black sheets, 28-16 B.W.G., are used for enamelware. Signs and water gauges are made from sheets of 20 or higher gauge. The steel produced in India is satisfactory for the manufacture of ordinary ware; for special purposes, however, low carbon steels and iron sheets are imported from U.S.A. The output of sheets in Indian mills is not sufficient to meet the demand of enamel factories.

Articles for enamelling are prepared by a variety of operations, such as cutting, punching, stamping, drawing, spinning, beading, and welding. For deep shapes, the articles are drawn a number of times with intermediate annealing.

Enamel frits are melted in pot or tank furnaces. The frit so made is poured into water and ground to a paste in ball mills with mill additions. Articles for enamelling are cleaned with acid, dipped in prepared slip, dried, and baked in muffle furnaces. Continuous furnaces fired with oil or heated by electricity are also used.

A wide range of enamelled ware including fire extinguishers, lanterns, reflectors, articles required for use in hospitals, and developing dishes used in photography, is produced in India. More



Sur Enamel Works Ltd., Calcutta

FIG. 85—ENAMELWARE LOADED IN TRUCKS FOR DRYING

recently, cast iron ware with acid-resisting enamel is being produced to meet the requirements of railways and the chemical industry.

Enamelware from sheet iron produced in India is comparable in quality and finish to the best produced in Europe and America. The cost of manufacture, however, is high mainly due to the heavy customs duty on imported raw materials, and the high cost of steel. The main obstacle for rapid development of cast iron enamelware is the non-availability of high grade castings. Good results have been obtained with imported castings.

Table 7 gives an indication of the annual output of the major items from Indian factories [*Panel Rep. Iron and Steel (Minor)*, Govt. of India, 1950, 66].

Table 8 gives the production during the period 1947-51.

Imports—Table 9 gives the imports of enamelware into India.

TABLE 7—ANNUAL PRODUCTION CAPACITY OF ENAMELWARE FACTORIES

| | Qty (pieces) |
|--|------------------|
| Rice plates, 10-16 cm. | 600,000 |
| do. do. 18-26 cm. | 1,200,000 |
| Flat plates, 9-16 cm. | 800,000 |
| do. do. 18-26 cm. | 1,600,000 |
| Soup plates, 22, 24, 26 cm. | 300,000 |
| Mugs, 9 and 10 cm. | 600,000 |
| Bowls, 10, 11, 12 and 13 cm. | 400,000 |
| Wash basins, 30, 32, 34, 36 and 40 cm. | 500,000 |
| Hospital and sanitary ware | 200,000 |
| Miscellaneous enamelware | 1,000,000 |
| Total | 7,200,000 |

TABLE 8—PRODUCTION OF ENAMELWARE

| | Qty (in thousand pieces) |
|------|-----------------------------|
| 1947 | 8,532.0 |
| 1948 | 6,763.2 |
| 1949 | 6,590.4 |
| 1950 | 5,445.6 |
| 1951 | 8,125.2 |
| 1952 | 7,701.6 |

The average value of annual imports after World War I was about Rs. 30 lakhs. The imports declined after 1931 due to increased production in India and competition from aluminium ware. The principal supplier during the period



Sur Enamel Works Ltd., Calcutta

FIG. 86—ENAMEL CUPS SUPPORTED ON PERRITS FOR FIRING

ENAMELWARE

TABLE 9—IMPORTS OF ENAMELWARE

| | Val. (Rs.) |
|-----------------------|---------------|
| 1934/35-1938/39 (av.) | 15,76,822 |
| 1939/40-1943/44 (av.) | 5,87,016 |
| 1944-45 | 37,587 |
| 1945-46 | 85,787 |
| 1946-47 | 2,10,678 |
| 1947-48 | 3,27,022 |
| 1948-49 | 1,50,636 |
| 1949-50 | 6,46,332 |
| 1950-51 | 1,87,089 |
| 1951-52 | 77,730 |
| 1952-53 | 2,64,786 |

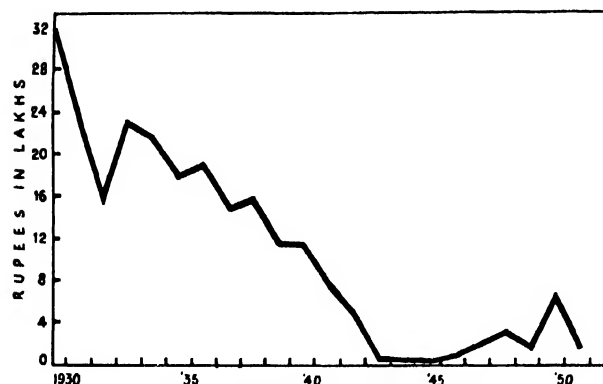


FIG. 87—IMPORTS OF ENAMELWARE

between the two World Wars was Japan, and cheap enamelware from that country almost threatened to kill the indigenous industry. The position was saved by the outbreak of World War II when exports from Japan ceased. The shares of various countries in the import of enamelware during the quinquennium ending March 1939 were: Japan, 54.5; Czechoslovakia, 17.1; U.K., 8.9; and Germany, 5.8%.

Imported enamelled iron ware is subject to the following rates of duty: sign boards, revenue duty of 25% *ad valorem* or 4½ as. per sq. ft. whichever is higher +1/5 of the total duty; domestic hollow-ware up to 19 cm. diam., revenue duty of 25% *ad valorem* or 4 as. per doz. for every 2 cm. or part thereof by which any diameter exceeds 11 cm., whichever is higher +1/5 of the total duty; domestic hollow-ware exceeding 19 cm. diam., revenue duty of 25% *ad valorem* or 8 as. per doz. +2 as. for every 2 cm. or part thereof by which any diameter exceeds 19 cm., whichever is higher +1/5 of the total duty.

ART ENAMELLING

Few handicrafts in India depend more for quality and beauty on the skill of the worker than art enamelling. Jaipur art on gold, silver,

brass, and copper enjoys world wide reputation. Excellent enamel work on jewellery is carried out in Delhi. Silver art work of Punjab, Kashmir, Cutch, Rampur, and Lucknow and copper and brass work of Jaipur, Kashmir, Punjab, Alwar, and Banaras, are also well known.

Champleve work of Jaipur, Cutch, Delhi, Lucknow, Banaras, and Rampur is carried out as follows: the metal is engraved or chased, repoussed, or blocked out in such a way as to provide depressions as per pattern. Oxides of metals of varying hue are arranged in the scooped depressions and fixed by firing. The goldsmith makes the article, the artist draws the design, and the engraver deftly uses his steel styles to prepare the pattern. The enameller (*minakar*) burnishes the surface and applies the colour paste with a probe in the order of their fusibility beginning with the least fusible. Borax is used as flux; it also imparts opacity to the enamel. The chief colouring materials used are: chromate of potash (for yellow), carbonate of manganese (for violet), cobalt oxide (for blue), copper oxide (for green), red iron oxide (for brown), and cobalt, copper, manganese, and red iron oxides (for black) along with quartz, borax, and red lead. The application of pure ruby red on gold requires great skill and is regarded as the high light of the art work of Jaipur, Delhi, and Banaras. White or ivory colour is obtained by the addition of antimonate of potash, hydrated iron oxide, and carbonate of zinc. Fired pieces are polished with corundum, slightly heated, soaked in an acid solution of fruit juice, and finally repolished for the market.

The technique employed in most parts of Kashmir consists in painting the surface with a silicated or readily fusible paint and subjecting the article to heat sufficient to melt the paint.

Art ware is produced in Pratapgarh (Rajasthan) by a novel technique. Articles made of green or red coloured glass or enamel are imported from Kashmir. A silver wire frame replica of the article is made and a sheet of fairly thick gold leaf is laid on, embedded in lac, and the pattern punched out and chased on gold. The glass is then semi-fused and while still hot, the rim of silver and the film of gold are slipped over the edge and pressed to the surface of the glass. The article is again heated until the gold and the glass get cemented together. Before mounting the article, a piece of silver tinfoil is placed underneath the glass to give brilliancy.

In the form of enamelling known as *cloisonne*, wires are fastened by gum or welded into a design. The spaces are loaded with colouring materials and fused. Art work of this type is common in China and Japan.

Enamelled articles cover a wide range,— handles

of swords, daggers, fans, and umbrellas; elephant, camel, and horse trappings; combs; shields; boxes; plates and trays; spoons; jugs; vases; and bowls. The enamelled gold staff of Maharaja Man Singh and an ink stand made in the form of a boat shaped like a peacock, its tail and head exquisitely enamelled in striking colours which glow in light, are two outstanding specimens of Jaipur art work.

Enamelled jewellery include necklaces with octagonal or oval shaped plaques, leaf shaped edges, and pendants of fish pattern, all worked in beautiful harmony with red, green, blue, and white enamel; choker with translucent birds on one side and uncut diamonds on the other; mango shaped lockers, embossed with flowers in red and white, to hold perfume; pendants of all shapes; ear-rings matching a star for the lobe of the ear and a hanging *jhumka* or bell delicately covered with sprays; bracelets; bangles; and hair ornaments. An enamelled bracelet of 5 tolas takes 15-20 days for completion (Bhavani, *Illustrated Weekly of India*, 1950, Dec. 17, 44). Production figures are not available.

ESSENTIAL OILS

Essential Oils, also called Ethereal or Volatile Oils, are volatile odoriferous bodies of an oily character derived mostly from vegetable sources. They occur, as a rule, in small concentrations in special cells, glands or ducts, either in one particular organ of the plant or distributed over many parts, e.g. leaves, barks, roots, flowers, or fruits. Occasionally they are present in combination with sugars as glycosides, e.g. amygdalin in bitter almonds and sinigrin in mustard seeds, and are liberated when the glycosides are hydrolyzed. Essential oils are insoluble in water, but freely soluble in alcohol, ether, fatty oils, and mineral oils. They are commonly liquid at ordinary temperatures and some of them deposit solid matter on standing. Many of them are optically active, are lighter than water, and possess a high refractive index. They are composed of a number of chemical compounds—hydrocarbons, alcohols (straight chain, terpene, phenol), esters, aldehydes, ketones, oxides and lactones, and occasionally, compounds of nitrogen and sulphur.

Essential oils may be separated from plant materials by one or the other of the following methods: (1) distillation, applicable to a wide range of materials, (2) expression by hand or machinery, applicable especially to fruit rinds, and (3) extraction by volatile solvents, hot oils or fats (maceration), or cold neutral fats (enfleurage) (*Encyclopaedia Britannica*, 8, 720).

Distillation—A large number of volatile oils are obtained either by boiling the vegetable matter in water contained in a closed vessel heated by open fire or by blowing live steam generated in a

separate boiler through the material. In both cases the vessel is connected at the top to a condenser through which the steam carrying the volatile oil passes. The distillate consisting of water and oil is collected in a receiver. In the water-distillation process, the charge is supported on a false bottom or placed in a wire basket and suspended inside the vessel to prevent direct contact with the heated bottom of the vessel.

Permeable materials, e.g. leaves, flowers, and grasses, are subjected to distillation without any pre-treatment. Materials, such as seeds, fruits, roots, and stalks are disintegrated before charging them into the still. The rate of distillation may be increased by working the still under pressure or by the use of superheated steam, provided the higher temperature obtained does not have a deleterious effect on the oil. Sometimes a partial drying of the material aids distillation though there is the risk of losing the volatile oil by evaporation or by oxidation.

In the distillation process, the material is exposed for a relatively long period to the action of steam or boiling water and the unstable aromatic constituents of the oil are likely to be affected. Further, side effects, such as hydrolysis, polymerization, and resinification, may take place. The higher boiling constituents of the volatile oil, if soluble in water, are not readily carried over by steam. Some of the volatile constituents dissolve in the water layer of the distillate and cannot be recovered. In consequence, the distilled oil does not always represent the natural oil as present in the plant material. Certain types of materials, particularly flowers with fugitive odours, are not suitable for treatment by the distillation process.

Expression—Citrus oils are obtained mainly by expression. In the 'sponge' process the peel is separated from the pulp, steeped in water to render the cells turgid, and, after draining, the peel is pressed between sponges. The sponges are then squeezed out and the oil collected. In the 'ecuelle' process whole fruits are placed in hollow vessels with spikes inside and rolled about. The oil cells are ruptured and the oil flowing out is collected in a receptacle (*Encyclopaedia Britannica*, 8, 721).

Machines are employed for extracting oils from bergamots and lemons. Special machines, e.g. Sfumatrice used in Italy, are capable of processing up to 10,000 lemons per day. Sometimes whole fruits are pressed and the juice and oil which run out together are collected and centrifuged to separate the oil. A large part of the lemon oil of commerce is obtained as a by-product in the preparation of lime juice.

Solvent extraction—In this method, which is particularly suitable for flowers, a volatile solvent,

ESSENTIAL OILS

such as petroleum ether, benzene, or alcohol, is employed for extracting the aromatic principles. The material is charged into a battery of closed cylinders and the solvent, which has been previously purified, is allowed to run through. The last cylinder is connected to a vacuum still and the solvent recovered by distillation at low pressure. The residue in the still, consisting of the aromatic principles and waxy substances is called the 'concrete.' It is shaken with alcohol to separate the insoluble waxes and cooled in a freezing mixture to separate the soluble waxes. The wax-free extract is distilled *in vacuo* to remove the alcohol, when the 'absolute' flower oil is obtained.

'Enfleurage' is employed for extracting fugitive perfumes from flowers, particularly those in which physiological activities leading to the formation and emission of perfumes continue for some time after gathering. The flowers are spread out lightly on glass plates both sides of which are smeared over by a specially prepared and purified mixture of beef and pork fats. The plates are supported in a wooden frame and placed one above the other in a closed chamber. Exhausted flowers are replaced by fresh ones and this process is repeated until the fat is saturated with the flower oil. The treated fat, known as 'pomade', is collected, extracted with alcohol, and the volatile oil isolated from the alcoholic extract by distillation under vacuum.

The 'maceration' process consists in immersing the flowers in oils and fats heated to c. 65°. The heat ruptures the cells and the flower oil goes into solution. This process is commonly employed in the preparation of perfumes and hair oils.

Terpeneless oils—The main odorous constituents of essential oils are oxygenated compounds. Terpenes and sesquiterpenes possess but little odour value. The latter, on account of their liability to atmospheric oxidation, affect the keeping quality of the oils. Terpeneless oils are prepared from natural oils by removing terpenes and sesquiterpenes by fractional distillation *in vacuo*, or by extracting the more soluble oxygenated compounds with dilute alcohol or other solvent followed by the removal of the solvent at low temperature.

Uses—Essential oils and aromatic chemicals are used in the following industries: (1) soap and cosmetics, (2) pharmaceuticals, (3) confectionery and aerated water, and (4) attars, scented tobacco, *agarbatti*, incense, etc. The Indian soap industry consumed 3,269 cwt. of essential oils in 1948. In addition, 661 cwt. of aromatic chemicals were

consumed. The pharmaceutical industry consumes annually c. 60,000 lb. of essential oils in addition to the quantity used by dispensing chemists (estimated to cost Rs. 2 lakhs). Some of them, e.g. thymol and eucalyptol, are valued in medicine on account of their disinfectant value and some, e.g. camphor, on account of their analgesic value. Flavouring essences, such as ginger, lemon, orange, vanilla, pineapple, raspberry, and rose, mainly derived from essential oils, are used in confectionery and aerated water industries. The value of essences consumed in these industries is estimated at Rs. 10 lakhs per annum. The total consumption of essential oils in India is nearly Rs. one crore per annum [*Third Census of Manufactures*, 1948, I, 276; Narielwala & Rakshit, *Rep. Essent. Oil Adv. Comm. (Exploratory)*, C.S.I.R. Monograph, 1946, 29].

Oil of turpentine is used on an extensive scale in the manufacture of paints and varnishes. It is also used as a source of synthetic camphor. Some oils are used as paint vehicles, especially in the painting of pottery and glass.

THE INDIAN INDUSTRY

The more important essential oils produced in India at present are sandalwood oil, lemongrass oil, palmarosa oil, eucalyptus oil, *khus* oil, linaloe oil, and turpentine oil. Small quantities of other oils, e.g. oils of ajowan, gingergrass, rose, lime, geranium, dill, and camphor, are also produced.

Attempts are being made to cultivate aromatic plants with a view to utilize them as sources of essential oils. Climatic conditions in the Himalayan ranges and on the Nilgiris are favourable for the cultivation of true lavender. A few varieties of lavender have been grown in the lower altitudes of Nilgiris and Sheveroy hills. Clove trees are grown in Travancore-Cochin and possibilities for the cultivation of cloves in other parts of India have been surveyed by the Indian Council of Agricultural Research. The production of peppermint oil in U.P. has been investigated [Narielwala & Rakshit, *Rep. Essent. Oil Adv. Comm. (Exploratory)*, 32; Dhingra *et al.*, *Indian Soap J.*, 1951, 17, 43].

Sandalwood oil, linaloe oil, and turpentine oil are produced on a factory scale in India. Other oils are produced on a cottage industry basis in indigenous pot-stills.

The total production of oils in India is estimated at about 2,760 tons made up as follows: cinnamon leaf oil, 33; sandalwood oil, 150; lemongrass oil, 500; palmarosa oil, 50; eucalyptus oil, 50; *khus* oil, 5; linaloe oil, 3; and turpentine oil, 2,000 tons (*Indian Soap J.*, 1949, 15, 9).

TABLE 1—EXPORTS OF ESSENTIAL OILS

| | Qty (gal.) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1934/35-1938/39 (av.) | 114,699 | 24,43,653 |
| 1939/40-1943/44 (av.) | 104,729 | 32,33,470 |
| 1944-45 | 134,412 | 53,58,426 |
| 1945-46 | 168,400 | 1,00,69,568 |
| 1946-47 | 151,044 | 1,46,32,394 |
| 1947-48 | 104,880 | 78,56,709 |
| 1948-49 | 111,653 | 46,91,720 |
| 1949-50 | 119,086 | 1,15,73,502 |
| 1950-51 | 174,978 | 2,50,10,532 |
| 1951-52 | 144,320 | 2,10,69,022 |
| 1952-53 | 126,477 | 1,10,70,442 |

In addition to the oils, a few aromatic products, such as scented hair oil, attars, and perfumed waters, are produced in India. Kanauj in Uttar Pradesh is the most important centre for these products. Scented hair oils are prepared by a modified enfleurage process in which the perfumes of flowers are absorbed directly by oilseeds. Thus for the preparation of scented sesamum oil, wetted sesamum seeds are placed in alternate layers with flowers and left over for 12 to 18 hours; the seeds are then crushed in a mill. Attars are made by absorbing the perfume vapour from the distillation still in sandalwood oil; occasionally paraffin oil is employed for absorbing the perfumes. The proportion of flower oil determines

the quality of attar and the more predominant the flower note, the higher its price. It is reported that several lakhs of rupees worth of attars are manufactured every year at Kanauj. Perfumed waters are produced by absorbing the perfume from rose and keora flowers in water and redistilling the water 2-3 times with fresh flowers [Narielwala & Rakshit, Rep. Essent. Oil Adv. Comm. (Exploratory), 24].

India exports lemongrass oil, sandalwood oil, palmarosa oil, gingergrass oil, oil of thymol, and citronella oil (Table 1). Besides, considerable quantities of aromatic seeds (c.g. ajama, ajowan, anise, coriander, cumin, dill, fennel, fenugreek) spices (cardamom, pepper, ginger, and turmeric), and sandalwood are exported to other countries for the production of essential oils (Table 2). Small quantities of cinnamon quills and bark are exported from the west coast of Madras.

India imports a variety of essential oils, such as almond, bergamot, cajuput, camphor, clove, dill, eucalyptus, lavender, lemon, otto rose, and peppermint and also synthetic oils. Tables 3 and 4 give the imports of essential oils into India.

There is considerable scope for the development of the Indian essential oil industry. In addition to the materials which are now being exploited for the production of essential oils, a large number of other plant materials, such as *davana* (*Artemisia pallens*), *valerian* (*Valeriana wallichii*), *Indian olibanum* (from *Boswellia serrata*), *Ocimum*

TABLE 2—EXPORTS OF AROMATIC MATERIALS
(Qty in tons and Val. in Rs.)

| | 1949-50 | | 1950-51 | | 1951-52 | | 1952-53 | |
|--------------------------|---------|--------------|---------|--------------|---------|--------------|---------|--------------|
| | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. |
| Seeds : | | | | | | | | |
| Ajama | 65 | 42,641 | 61 | 53,483 | 154 | 1,65,522 | 73 | 54,141 |
| Ajowan | 111 | 77,829 | 143 | 1,37,099 | 256 | 2,61,755 | 240 | 1,78,428 |
| Anise | 43 | 31,418 | 58 | 67,964 | 130 | 2,29,322 | 24 | 62,356 |
| Coriander | 3,387 | 26,51,459 | 2,892 | 44,44,826 | 1,580 | 29,36,085 | 967 | 9,77,903 |
| Cumin (black) | 74 | 91,950 | 71 | 1,95,645 | 24 | 1,17,182 | 14 | 58,130 |
| Cumin (other than black) | 273 | 4,49,032 | 958 | 19,30,406 | 2,220 | 48,56,466 | 1,242 | 21,01,725 |
| Dill | 346 | 2,15,194 | 323 | 2,71,026 | 299 | 2,80,978 | 292 | 2,52,452 |
| Fennel | 2,091 | 14,60,720 | 1,428 | 14,26,606 | 1,217 | 22,15,062 | 758 | 15,64,221 |
| Fenugreek | 707 | 5,67,806 | 509 | 5,84,126 | 1,032 | 8,18,690 | 1,063 | 5,52,903 |
| Other sorts | 90 | 46,588 | 1 | 2,130 | 115 | 1,69,598 | 154 | 1,63,408 |
| Spices : | | | | | | | | |
| Cardamom | 817 | 1,25,18,513 | 622 | 1,47,60,675 | 693 | 1,64,15,710 | 968 | 1,63,73,327 |
| Cinnamon | 4 | 6,100 | .. | .. | .. | .. | .. | .. |
| Cloves | 5 | 12,262 | .. | .. | .. | .. | .. | .. |
| Ginger | 1,507 | 41,71,128 | 2,198 | 92,40,671 | 2,620 | 84,65,504 | 3,217 | 52,10,821 |
| Pepper | 15,631 | 14,50,46,135 | 15,394 | 20,40,32,811 | 14,914 | 23,22,27,311 | 12,311 | 15,95,91,125 |
| Turmeric | 8,643 | 1,10,22,088 | 10,280 | 1,25,83,161 | 10,585 | 1,00,26,032 | 7,630 | 46,69,855 |
| Wood : | | | | | | | | |
| Sandal | 772 | 23,39,430 | 1,075 | 37,62,043 | 607 | 21,07,924 | 912 | 32,01,126 |

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TABLE 3—IMPORTS OF ESSENTIAL OILS
(Qty in lb.)

| | 1934/35- 1938/39 (av.) | 1939/40- 1943/44 (av.) | 1944-45 | 1945-46 | 1946-47 | 1947-48 | 1948-49 | 1949-50 | 1950-51 | 1951-52 | 1952-53 |
|-------------|------------------------------|------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Synthetic | 18,236 | 10,020 | 6,631 | 16,686 | 25,160 | 57,318 | 55,169 | 16,520 | 26,653 | 37,189 | 29,096 |
| Natural : | | | | | | | | | | | |
| Almond | 167 | 18 | 17 | 53 | 8 | 425 | 3 | 27 | 14 | 152 | 26 |
| Bergamot | 725 | 389 | 286 | 726 | 820 | 2,481 | 235 | 582 | 903 | 580 | 252 |
| Cajuput | 1,201 | 395 | .. | 9 | 205 | 198 | 122 | 241 | 414 | 211 | 150 |
| Camphor | 7,878 | 1,292 | 23 | 61 | 859 | 1,615 | 293 | 360 | 119 | 212 | 769 |
| Clove | 1,172 | 814 | 1,563 | 607 | 1,203 | 1,988 | 934 | 2,631 | 1,781 | 1,936 | 1,205 |
| Dill | * | * | .. | .. | 17 | 17 | 8 | 6 | 5 | .. | 1 |
| Eucalyptus | 1,916 | 520 | 100 | 82 | 2,704 | 1,158 | 431 | 2,332 | 759 | 468 | 12 |
| Lavender | 1,288 | 684 | 162 | 1,090 | 1,890 | 1,938 | 397 | 2,943 | 2,184 | 3,041 | 1,129 |
| Lemon | 1,835 | 1,181 | 475 | 1,887 | 3,144 | 2,897 | 1,410 | 2,183 | 1,980 | 1,428 | 669 |
| Otto Rose | 21 | 49 | 82 | 70 | 569 | 347 | .. | 80 | 87 | 49 | 21 |
| Peppermint | 1,987 | 1,646 | 140 | 1,172 | 3,086 | 1,057 | 905 | 2,885 | 3,382 | 2,424 | 1,779 |
| Other sorts | 27,204 | 43,760 | 37,453 | 60,440 | 78,981 | 119,947 | 64,492 | 35,043 | 47,942 | 86,831 | 56,387 |
| Total | 63,630 | 60,768 | 46,932 | 82,883 | 118,646 | 191,386 | 124,399 | 65,833 | 86,223 | 134,521 | 91,486 |

* negligible

TABLE 4—IMPORTS OF ESSENTIAL OILS
(Val. in thousand Rs.)

| | 1934/35- 1938/39 (av.) | 1939/40- 1943/44 (av.) | 1944-45 | 1945-46 | 1946-47 | 1947-48 | 1948-49 | 1949-50 | 1950-51 | 1951-52 | 1952-53 |
|-------------|------------------------------|------------------------------|---------|---------|----------|----------|---------|---------|---------|----------|---------|
| Synthetic | 704.0 | 521.1 | 825.2 | 2,368.3 | 3,664.9 | 6,519.5 | 4,818.7 | 1,839.4 | 3,691.2 | 5,936.7 | 4,178.4 |
| Natural : | | | | | | | | | | | |
| Almond | 3.1 | 0.8 | 1.1 | 2.5 | 1.0 | 120.0 | 0.1 | 1.2 | 0.6 | 9.1 | 2.9 |
| Bergamot | 38.4 | 35.4 | 55.0 | 189.3 | 182.2 | 263.0 | 36.5 | 75.9 | 171.2 | 141.7 | 113.2 |
| Cajuput | 15.4 | 8.0 | .. | 0.9 | 10.2 | 14.0 | 5.5 | 13.2 | 21.9 | 15.6 | 8.3 |
| Camphor | 18.7 | 5.0 | 1.0 | 0.8 | 7.0 | 15.6 | 2.6 | 2.9 | 1.3 | 10.2 | 8.0 |
| Clove | 33.5 | 42.2 | 113.1 | 44.6 | 80.5 | 112.3 | 48.9 | 132.3 | 142.1 | 190.5 | 91.3 |
| Dill | * | * | .. | .. | 0.8 | 3.8 | 2.8 | 1.5 | 1.7 | .. | 0.2 |
| Eucalyptus | 28.1 | 10.2 | 5.4 | 4.0 | 77.0 | 32.2 | 25.4 | 60.7 | 42.9 | 16.7 | 1.0 |
| Lavender | 89.2 | 52.6 | 25.5 | 145.8 | 425.2 | 272.7 | 41.0 | 262.4 | 214.3 | 491.7 | 194.0 |
| Lemon | 66.7 | 98.3 | 53.4 | 217.1 | 355.5 | 317.0 | 137.0 | 170.6 | 200.9 | 305.1 | 129.0 |
| Otto Rose | 4.2 | 3.6 | 1.0 | 17.0 | 90.8 | 45.9 | 2.4 | 8.0 | 16.4 | 10.2 | 3.7 |
| Peppermint | 72.3 | 85.8 | 38.1 | 242.0 | 396.1 | 118.5 | 117.7 | 375.9 | 536.7 | 614.0 | 325.9 |
| Other sorts | 417.6 | 745.9 | 1,663.0 | 2,485.3 | 4,854.1 | 3,691.3 | 2,267.6 | 1,638.0 | 2,241.1 | 5,163.1 | 2,677.2 |
| Total | 1,491.2 | 1,608.9 | 2,781.8 | 5,717.6 | 10,145.3 | 11,525.8 | 7,506.2 | 4,582.0 | 7,282.3 | 12,904.6 | 7,733.1 |

* negligible

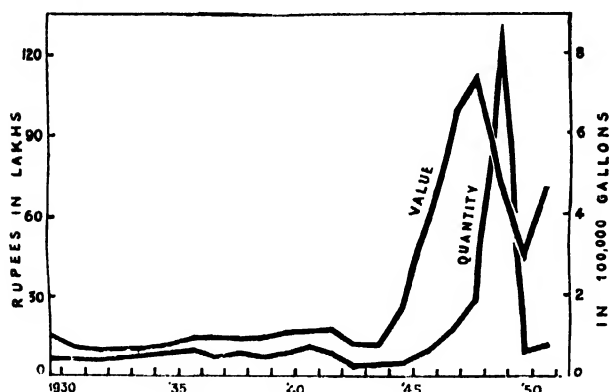


FIG. 88—IMPORTS OF ESSENTIAL OILS

kilimandscharicum, *Michelia champaca*, *Jasminum* spp., and certain grasses belonging to the *Cymbopogon* genus are found in India but are not being utilized as sources of aromatic oils and chemicals.

Ajowan Oil

Ajowan oil is obtained from the seeds of *Trachyspermum ammi*. Prior to World War I ajowan seeds were exported to Europe and U.S.A. for the production of oil from which thymol was being prepared. Since the introduction of synthetic thymol, however, the distillation of ajowan seeds for oil has practically ceased outside India.

The oil is produced on a commercial scale by steam distillation at Rao (Indore). Small quantities are produced in U.P. The percentage yield

of oil on the weight of seeds is usually 3-4. A yield of 9% oil is reported from the seeds of plants grown in Seychelles. Thymol crystals are recovered from ajowan oil by treatment with caustic soda solution and precipitation with sulphuric acid. The yield is c. 1% on the weight of seeds. The aqueous distillate, left after the separation of oil, is sold in India as 'omum water' and used in the treatment of disorders of the stomach. 'Thymoil', which is the name given to the residue left after the separation of thymol crystals, is obtained as a by-product. The residue from the distillation still is used as cattle fodder or as manure.

Ajowan oil is an almost colourless or brownish yellow liquid with the odour of thyme and a sharp burning taste. The oil becomes darker on keeping. It has the following characteristics: sp. gr.^{15°}, 0.91-0.93; $[\alpha]_D$, +1 to +5°; n_D^{20} , 1.498-1.504; solubility in 80% alcohol, 1-2.5 vol.; phenols, 45-57%. The presence of the following compounds has been established: α -pinene, p -cymene, dipentene, γ -terpinene, thymol, and carvacrol. Ajowan oil containing 30% phenols is toxic to earthworms at a concentration of c. 0.024% in alcohol. Extracts of seeds in 70% and 40% ethyl alcohol are toxic to *Staphylococci* and *Escherichia coli* when diluted to contain 10% extract but not when diluted to 2%. The same extracts diluted to 10% are useful as expectorants in emphysema, bronchial pneumonia, and other respiratory diseases (*Schimmel Rep.*, 1945, 3; *Gildemeister & Hoffman*, III, 496; *Guenther*, IV, 552).

Commercial thymene consists of p -cymene and other terpenes.

Statistics of production of ajowan oil are not available. Production in 1951 was reported to be 3,647 lb. of thymol crystals and 4,530 lb. of thyme oil. The corresponding production figures in 1952 were 2,118 lb. and 2,640 lb. The prices of ajowan oil and products derived therefrom in 1946 were: ajowan oil, Rs. 2-4-0/lb.; thymol, Rs. 6-4-0/lb.; and thymoil, Rs. 0-12-0/lb.

Cinnamon Oil

Cinnamon oil of commerce is derived from the bark and leaf of *Cinnamomum zeylanicum*. The largest producer of cinnamon oil is Ceylon; Seychelles occupies the second place.

Cinnamon oil is distilled in Malabar, South Kanara, Bangalore, and Augarakandy estate near Tellicherry. The oil is obtained from the leaves. Four kinds of *C. zeylanicum* are distinguished according to the taste of the leaves—sweet, insipid, pungent, and bitter. The leaves of only pungent (*tej*) and bitter (*kadwa*) types are used for the production of oil. They are packed in earthen vessels partially filled with water and distilled. The temperature is not allowed to rise

TABLE 5—CHARACTERISTICS OF CINNAMON LEAF OIL*

| No. | d^{20}_4 | n_D^{20} | Eugenol % | Acid. val. | Ester val. | Solubility in 70% alcohol (vol.) |
|---------------------|---------------|-------------|-----------|------------|------------|----------------------------------|
| 1. | 1.0443 | 1.5223 | 70.0 | .. | .. | 1.5 |
| 2. | 1.0615 | 1.5235 | 71.3 | .. | .. | 1.5 |
| 3. | 1.0620 | 1.5305 | 87.2 | 15.7 | 4.7 | 1.5 |
| 4. | 1.0540 | 1.5275 | 81.2 | 14.0 | 16.7 | 1.5 |
| 5. | 1.0431-1.066 | 1.53-1.54 | 70-95 | .. | .. | .. |
| 6. | 1.0206-1.0604 | 1.533-1.537 | 78-94 | .. | .. | 1-1.5 |
| 7. | 1.050 | 1.5350 | 85.50 | .. | .. | 1.0 |
| (at 15.5°) (at 20°) | | | | | | |

* *Krishna et al.*, *J. sci. industr. Res.*, 1945-46, 4, 464
No. 1, 2 & 3, distilled by Cardol Corporation, Mangalore from leaves grown in South Kanara; No. 4, distilled from leaves grown in North Malabar; No. 5, Ceylon leaf oil; No. 6, Seychelles leaf oil; No. 7, Cinnamon leaf oil of Augarakandy Oil Co. (North Malabar); aldehyde as cinamyl aldehyde, 1.4% (*Hughes & Davis*, Bombay)

above the boiling point of water and the distillation takes c. 16 hours. The oil collected in the receiver, being heavier than water, sinks to the bottom. The yield of oil is c. 0.71%. Improved stills for extracting the oil by steam distillation have been erected in the Augarakandy estate.

Properties and uses—Cinnamon leaf oil is a brown pungent liquid with a camphoraceous odour resembling that of cloves. Table 5 gives the characteristics of the oil.

Cinnamon leaf oil equals clove oil in eugenol content. It is used for flavouring confectionery and is a common adulterant for cinnamon bark oil. It is a convenient raw material for the extraction of eugenol from which vanillin and other products are prepared. It is used as an embrocation in rheumatism.

Production and trade—The average annual production of oil in North Mangalore is about 3,600 lb. It has been estimated that from North Kanara alone nearly 100,000 lb. of leaves can be collected (*Trotter*, 1940, 253).

The price of oil per lb. varied from 1s. 8d. to 2s. in 1938, and from 6s. to 8s. in 1947; the price was 13s. 3d. in May 1953. Being a source of eugenol the consumption and price of the oil follow closely those of clove oil (*Bull. imp. Inst.*, Lond., 1948, 46, 168).

India imports cinnamon leaf oil and cinnamon bark oil from Ceylon. Imports of the two oils in 1944 amounted to 272,000 oz.; in 1946, the quantity imported was 597,000 oz. (*Ceylon Yearb.*, 1948, 87).

Citrus Oils

The principal producers of citrus oils are Italy, U.S.A., Brazil, Israel, French West Africa, and

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TABLE 6—CHARACTERISTICS AND COMPOSITION OF OILS FROM INDIAN ORANGES*

| | Sp. gr. ^{15°} | | [α] _D | d-limonene (%) | Methyl anthranilate (%) | Crystalline wax (%) | Linalool (%) | Other esters (%) | Residue (%) |
|---------------------------|------------------------|--------|------------------|----------------|-------------------------|---------------------|--------------|---|-------------|
| Sylhet oil (hand pressed) | 0.8413 | 1.4730 | +113.3° | 94.14 | 0.20 | 0.56 | nil | 3.1 | 2.00 |
| Coorg oil (cold pressed) | 0.8553 | 1.4730 | +114.3° | 94.06 | 0.12 | 0.21 | 0.18 | Nonyl caprylate, 2.04; unidentified, 0.82 | 2.57 |
| Nagpur oil (distilled) | 0.8501 (at 15°) | 1.4680 | + 85.03° | 90.80 | 0.80 | trace | 1.80 | 4.0 | 1.90 |
| Coorg oil (distilled) | 0.8494 | 1.4750 | +114.0° | 93.58 | 0.17 | .. | 1.01 | 3.9 | 1.33 |
| Coorg oil | 0.8476 | 1.4700 | +114.0° | 96.63 | 0.32 | .. | 0.64 | Citral, 0.48; unidentified, 1.93 | .. |

* Nigam & Dutt, *Indian Soap J.*, 1946, 11, 245

TABLE 7—IMPORTS OF CITRUS OILS

| | Bergamot oil | | Lemon oil | |
|-----------------------|--------------|------------|------------|------------|
| | Qty (gal.) | Val. (Rs.) | Qty (gal.) | Val. (Rs.) |
| 1934/35-1938/39 (av.) | 752 | 38,462 | 1,835 | 66,765 |
| 1939/40-1943/44 (av.) | 389 | 35,454 | 1,181 | 98,290 |
| 1944-45 | 286 | 54,991 | 475 | 53,369 |
| 1945-46 | 726 | 1,89,263 | 1,887 | 2,17,065 |
| 1946-47 | 820 | 1,82,219 | 3,144 | 3,55,441 |
| 1947-48 | 2,481 | 2,63,020 | 2,897 | 3,17,026 |
| 1948-49 | 235 | 36,503 | 1,410 | 1,36,998 |
| 1949-50 | 582 | 75,921 | 2,183 | 1,70,561 |
| 1950-51 | 903 | 1,71,215 | 1,980 | 2,00,909 |
| 1951-52 | 580 | 1,41,732 | 1,428 | 3,05,087 |
| 1952-53 | 252 | 1,13,184 | 659 | 1,28,955 |

Algeria. Bergamot oil is produced in Italy; grapefruit oil in U.S.A. and Brazil; lemon oil in Sicily, U.S.A., and Mexico; lime oil in Trinidad (West Indies), British Guiana, and Mexico; mandarin oil in Sicily and Spain; and orange oil in Sicily, Florida and California, Brazil, Jamaica, Palestine, and Tanganyika.

There is no organized citrus oil industry in India. Two types of citrus oils are produced on a small scale. Lime oil is distilled in Utrain in East Khandesh (Bombay State) from *Citrus aurantifolia* and orange oil from *Citrus reticulata* (kamala, narangi, santara) in Coorg and Nagpur. Both oils are obtained from fresh peels by

mincing and steam distillation. Orange oil is also obtained by expression.

Oil of lime produced in India has the following constants: sp.gr.^{30°}, 0.8533-0.8547; [α]_D^{31°}, 38.5-45.22; *n*_D^{30°}, 1.4710-1.4720; acid val., 0.89-1.1; ester val., 1.93-2.4; citral, 0.94-1.1%; and non-volatile residue, 2.21-2.5% (Krishna & Badhwar, *J. sci. industr. Res.*, 1948, 7, suppl., 98).

Table 6 gives the composition of orange oils.

The production of citrus oils in India amounted to 149 lb. in 1951 and 291 lb. in 1952. The annual production capacity is estimated to be 13,980 lb. Table 7 gives the imports of citrus oils into India.

Eucalyptus Oil

The genus *Eucalyptus* comprises over 500 species and a large number of them has been utilized for the production of aromatic oils. The oils obtained by the steam distillation of leaves and terminal branches of various species are distinctive in character. Three types of oils are ordinarily recognized: (1) medicinal oil (or cineole oil), (2) industrial oil (or phellandrene oil), and (3) perfumery oil.

Australia is the largest producer of eucalyptus oils. About two-thirds of the world's supply of medicinal oil and one-third of industrial oil come from that country. In 1946-47, Australia exported 186,000 gal. of eucalyptus oils; her annual consumption was 60,000 gal. (medicinal oil, 10,000 gal.; industrial oil, 50,000 gal.). Other producers of eucalyptus oils are Belgian Congo, Spain, and Portugal. Belgian Congo produces annually 20

metric tons of medicinal oil, 3 metric tons of industrial oil, and 1 metric ton of perfumery oil. Spain and Portugal produce only medicinal oil, the annual production in pre-war years from these countries being respectively 60-100 tons and 10 metric tons. During World War II when supplies of Australian oil became scarce Brazil and Guatemala were producing eucalyptus oil.

About 93% of the medicinal oil produced in Australia is derived from *E. polybractea*, *E. sideroxylon*, *E. leucoxylon*, *E. australiana*, and *E. dives* var. C. The balance is obtained from *E. elaeophora*, *E. cneorifolia*, *E. viridis*, *E. dumosa*, and *E. smithii*. Belgian Congo produces medicinal oils from *E. globulus* and *E. smithii*, and Spain, Portugal, and Brazil from *E. globulus*.

The following plants are utilized in Australia for the manufacture of industrial oil: *E. dives* 'Type,' *E. australiana*, var. B, *E. dives*, var. A, *E. numerosa*, and *E. numerosa* var. A. *E. dives* is the source of industrial oil in Belgian Congo.

Both Australia and Belgian Congo obtain perfumery oil from *E. macarthurii*; *E. citriodora* is the source of perfumery oil in Guatemala.

Eucalyptus oil is obtained in India by the distillation of leaves and terminal branchlets of *E. globulus* (Blue Gum tree), which grows on Nilgiri, Annamalai, and Palni hills. The oil is produced on a cottage industry basis. More recently scientific methods of processing and refining have been introduced.

The leaves are collected from trees felled for supplying fuel to Ootacamund and other towns in the hills. Mature leaves from trees of 15 years and above are preferred. They are dried in shade for 3 days and subjected to distillation in stills (charge per still, 800 lb. of leaves and 36 gal. of water). The crude oil is separated from the distillate, filtered through paper, and refined by redistillation after adding caustic potash (yield,

120 oz. per 800 lb. of leaves). The refined oil is again passed through filter paper and bottled for marketing (Trotter, 1940, 253).

Properties and uses—Eucalyptus oil is a colourless to pale yellow liquid with a characteristic aromatic, somewhat camphoraceous, odour and spicy taste. Table 8 gives the characteristics of oils distilled in Nilgiri and Australia.

Eucalyptus oil from Nilgiri contains: cineole, 62.0; pinenes, 24.0; pinocarveol, c. 0.4; cuminaldehyde, c. 0.5; sesquiterpene alcohols, 5.0; aromadendrene, 1.0; phenols, 0.3; low boiling alcohols, aldehydes, ketones, and acids, 2.5; and residue (mainly aluminium oxide), c. 3.0%. The cineole content is low as compared with the minimum specified (70%) in B.P. and U.S.P. The Indian Pharmacopoeial List (I.P.L.) 1946, however, specifies the minimum cineole content as 55%. In solubility also Indian oil does not conform to B.P. and U.S.P. specifications. The oil does not contain butyric and valeric aldehydes which are present in the Australian oil [Ramaswamy *et al.*, *Quart. J. Indian Inst. Sci.*, 1946, 9(2), 57].

The oil is used mainly for medicinal purposes. It is used as an antiseptic and deodorant. It is inhaled to relieve cough in chronic bronchitis, asthma, catarrhal colds, and to prevent infections. It is given internally in cases of catarrhal inflammation of mucous membrane, especially of the respiratory tract and bladder. An ointment containing the oil in soft paraffin is employed in the treatment of burns and as antiseptic dressing. It has also been used as a remedy against hookworm. Chlorinated cineole fractions with apparently high disinfectant properties have been obtained. It is employed commercially as an emulsifying agent. The oil is also used for scenting soaps [I.P.C., 178; Ramaswamy *et al.*, *Quart. J. Indian Inst. Sci.*, 1946, 9(2), 57].

Oil of *Eucalyptus citriodora* is being produced

TABLE 8—PROPERTIES OF EUCALYPTUS OIL.

| | Nilgiri oil ¹ | Nilgiri oil ² | Australian oil | B.P. | I.P.L. |
|-----------------------------|--------------------------|--------------------------|-----------------|----------------------|-------------------------------|
| Yield % | 0.9-1.2 | 1.18 | 0.92 | .. | .. |
| Sp. gr. | 0.902 (30°) | 0.9065-0.9155 (19°) | 0.913 (15°) | 0.904-0.924 (20°) | 0.9065-0.9155 (15.5°) |
| n_D^{20} | 1.4608 | 1.4630-1.4666 | 1.4663 | 1.458-1.470 | 1.4580-1.4700 |
| $[\alpha]_D$ | +9.68° | +5.28° to +9.39° | +8.4° | -5° to +5° | -5° to +10° |
| Acid val. | 6.3 | 0.104-0.18 | .. | .. | .. |
| Sap. val. | 37.5 | 8.9-20.0 | .. | .. | .. |
| Sap. val. after acetylation | 92.2 | 17.0-21.7 | .. | .. | .. |
| Cineole content, % | 62.2 | 56.0 | 57.0 | 70 | 60 |
| Solubility in 70% alcohol | Insol. in 10 vols. | Insol. | Sol. in 1.5 vol | Sol. in 5 vol. | Sol. in 1 vol. of 80% alcohol |

¹ Ramaswamy *et al.*, *Quart. J. Indian Inst. Sci.*, 1946, 9 (2), 57

² Puran Singh, *Indian For. Rec.*, 1917, 5 (8)

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on a small scale at Calicut (S. India). Citriodora oil is a valuable perfumery oil [Techno-chemical Industries Ltd., Kozhikode (Calicut), private communication].

Production and trade—The estimated acreage under *E. globulus* in Nilgiri was 2,400 acres in 1950. Due to the heavy demand for firewood and high prevailing prices for potatoes, eucalyptus trees are being felled and plantations converted into potato fields. The estimated production of eucalyptus oil in Nilgiri and Kodaikanal during 1949-50 was 40,000 lb. valued at Rs. 1.65 lakhs. The production of oil has fallen in recent years (Information from Forest Dep., Madras).

Table 9 gives the imports of eucalyptus oil into India. Of the total value of imports during the quinquennium 1934/35-1938/39, U.K. accounted for about 80% and Australia, for 17%.

Prices—The price of eucalyptus oil (cineole content, 70-75%) in the London market was 7s to 7s. 6d./lb. at the end of 1947, 5s. 3d. in June 1950, 4s. 9d.-5s. 1d. per lb. in Aug. 1953.

The Essential Oil Advisory Committee has made the following recommendations for the development of eucalyptus oil industry: (1) extension of eucalyptus cultivation in Nilgiri and in selected areas in U.P., Bihar, and Orissa,

and (2) cultivation of *Eucalyptus citriodora*, the oil of which is rich in citronellal [Narielwala & Rakshit, Rep. Essent. Oil Advisory Comm. (Exploratory), 1946, 16].

Geranium Oil

Oil of Rose Geranium, commonly known in the trade as Oil of Geranium, ranks high among essential oils used for perfuming toilet soaps. The only country in which true geranium oil is produced, though in small quantities, is Bulgaria, a particular species, *Geranium macrorrhizum*, being used as the source of the oil. For commercial purposes, the oil is obtained from *Pelargonium* spp., popularly called geranium. The world production of geranium oil is estimated at 150 tons, the bulk of which comes from Reunion Island. Other producers are Algeria, Morocco, France, Spain, Tunisia, Sicily, Madagascar, Belgian Congo, and Russia.

Pelargonium graveolens grows wild in Nilgiri. A trial distillation of the plant gave a yield of 0.044% oil. Cultivation of the plant on a plantation scale has been attempted on Yercaud hills (near Salem) from cuttings of *P. odoratissima* from Reunion Island. The plantation is now about 30 years old. Oil is being produced in Yercaud, though on a small scale. The yield is reported to be 8 lb. of oil per acre.

The material is gathered in bright sunshine when the leaves begin to turn yellow and their odour resembles that of roses. The material is charged into tin-lined copper stills and subjected to distillation. The oil collected in the receiver is occasionally green and a heavy black scum collects on the surface. The colour is due to copper and can be removed by shaking the oil in a separating funnel with 0.5% aqueous solution of tartaric acid (Bontilly, *Perfum. essent. Oil Rec.*, 1947, 8, 133).

Properties—Table 10 gives the characteristics of geranium oil. The principal constituents of the oil are geraniol and citronellol. Phenyl-ethyl

TABLE 9—IMPORTS OF EUCALYPTUS OIL

| | Qty (gal.) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1934/35-1938/39 (av.) | 1,916 | 28,134 |
| 1939/40-1943/44 (av.) | 520 | 10,170 |
| 1944-45 | 100 | 5,391 |
| 1945-46 | 82 | 3,988 |
| 1946-47 | 2,704 | 77,006 |
| 1947-48 | 1,158 | 32,162 |
| 1948-49 | 431 | 25,418 |
| 1949-50 | 2,332 | 60,731 |
| 1950-51 | 759 | 42,854 |
| 1951-52 | 468 | 16,899 |
| 1952-53 | 12 | 989 |

TABLE 10—CHARACTERISTICS OF GERANIUM OIL*

| | Oil, foreign | Indian oil | | |
|---|---------------------------------|-----------------------------|------------------------|------------------------|
| | | Yercaud | Nanjangud | Nilgiri |
| General appearance | Clear, light yellow to greenish | Yellowish green to greenish | Clear, yellowish green | Clear, yellowish green |
| Sp. gr. ^{15°} | 0.8906-0.8947 | 0.8998-0.9079 | 0.8946 | 0.8880 |
| | 1.4644-1.4674 | 1.4638-1.4708 | 1.4688 | 1.4600 |
| Temp. of sol. in 3 parts of 70 % (vol.) alcohol | 20° and below | 20° and below | 20° and below | 20° and below |
| Acid val. | 3.65-16.03 | 7.9-10.7 | 2.6 | .. |
| Ester, % as geranyl tiginate | 18.96-31.75 | 18.98-22.26 | 21.0 | 40.10 |
| Fluorescence in ultra-violet light | Greenish to bluish | Greenish to bluish | Bluish | Bluish |

Ramaswamy, *Oil of Geranium*, Bd Industr. Planning & Co-ordination, Govt. Mysore, 1942, 17

alcohol, linalool, menthol, and borneol are usually present. Oil from Reunion Island contains citronellol, geraniol, phenyl-ethyl alcohol, terpeniol, linalool, menthol, menthone, phellandrene, esters of tiglic, acetic, isobutyric, and isovaleric acids.

Palmarosa oil blended with phenyl-ethyl alcohol, diphenyl oxide, diphenyl methane, and genuine geranium oil, is sold in the market as geranium oil. Sometimes, esters of geraniol and citronellol are used to reinforce the rose-like odour of spurious oils. Gurjan balsam oil, turpentine, and cedarwood oil are used as adulterants. Adulteration can be detected by determining the solubility in 70% alcohol and the ester value. Adulterated oils have low solubility and low ester value.

Uses—Geranium oil has acquired importance in perfumery as it forms, along with *khos* and patchouli oils, the body of all good perfumes. It is the basis for the manufacture of rhodinol and its esters. Terpeneless geranium oil is a perfume in itself which blends well into every type of floral bouquet; it is particularly valuable as a base for artificial rose compounds. Geranium oil is used also for adulterating rose attar. An appreciable quantity of geranium oil is consumed in India for flavouring purposes.

Production and trade—The production of geranium oil in India was 2,006 lb. in 1951 and 1,083 lb. in 1952. The total annual demand is estimated at 10,000–12,000 lb. valued at Rs. 1.5–2 lakhs. About two-thirds of the quantity is used in the soap industry and the rest in the perfumery trade for adulterating rose water and attars. The price of geranium oil in 1946 was Rs. 25 per lb. The present price is about Rs. 85–100 per lb.

Climatic conditions prevailing in Nilgiri and Sheveroy hills are well suited for the cultivation of geranium and there is great scope for expanding the oil distilling industry in India. The Government of Madras, through its Department of Agriculture, has been supplying cuttings of geranium plants to those interested in the cultivation of geranium.

Gingergrass Oil

Gingergrass oil is obtained from the *sofia* variety of *Cymbopogon martini*. The grass grows gregariously in the forests of Malghat in Pimpalner and Nanurbar ranges of Khandesh district, Yeola and other ranges of Nasik district, and Dohad and Jholad ranges of Panch Mahals. The *sofia* variety of the grass is morphologically indistinguishable from the *motia* variety, which is the source of the commercially important palmarosa oil.

The oil is obtained by the distillation of the leaves, stalks, and flowers of the grass. The yield varies from 0.15% to 1% (dry basis). Gingergrass

oil is a brownish yellow, sweet smelling oil with the following characteristics: sp. gr.^{15°}, 0.900–0.953; $[\alpha]_D^{20}$, -30° to $+54^\circ$; n_D^{20} , 1.478–1.493; acid val., 6.2 (max.); ester val., 8–29; ester val. after acetylation, 120–200; total alcohol (calculated as geraniol), 36.3–64.7%; soluble in 2–3 vol. of 70% alcohol; opalescent to turbid with more alcohol. Geraniol is the chief constituent, other constituents being *d*-limonene, dipentene, *d*- α -phellandrene, an aldehyde of the formula $C_{10}H_{16}O$, dihydrocumyl alcohol, and *dl*-carvone (Guenther, IV, 19).

Gingergrass oil is used in perfume blends for scenting the cheaper varieties of soaps. The annual production is estimated at 4,000 lb. [Narielwala & Rakshit, Rep. Essent. Oil Advisory Comm. (Exploratory), 1946, 17].

The common adulterants of Indian gingergrass oil are mineral oil, gurjan balsam oil, and coconut oil. An oil similar to gingergrass oil in odour, constants, and properties is obtained from *kachi* grass (*Cymbopogon caesus*) found in Madras, Mysore, Travancore, and Gujarat. It is used as an adulterant for gingergrass oil.

The price of gingergrass oil in 1939 was about 7s. 3d. per lb. (ex store). When supplies became limited at the end of 1941, the price rose to 25s. per lb.; the price varied between 22s. 6d. and 25s. per lb. till the end of World War II. The price was 25s. per lb. in June 1950 and 70s. per lb. in May 1953.

Jasmine Oil

Grasse (France) is the world's largest producer of jasmine oil. The perfume is extracted by enfleurage and solvent extraction processes. Jasmine oil is not produced in India.

Table 11 gives the important species of jasmine (with their regional names) cultivated in India.

TABLE 11—SOME INDIAN JASMINE SPECIES

| | Regional names |
|------------------------|---|
| <i>J. arborescens</i> | <i>Naba mallica</i> (West Bengal), <i>Muta bela</i> (U.P.) |
| <i>J. auriculatum</i> | <i>Jui</i> (West Bengal), <i>Pindari</i> (Bombay & Baroda), <i>Kadaru mallige</i> (Madras), <i>Juhi</i> (U.P.) |
| <i>J. caudatum</i> | <i>Mallica</i> (West Bengal) |
| <i>J. flexile</i> | <i>Malati</i> (West Bengal), <i>Ramabanam</i> , <i>Nityamallige</i> (Madras) |
| <i>J. grandiflorum</i> | <i>Chambeli</i> (Bombay, Baroda & U.P.), <i>Mallat</i> , <i>Jajimalli</i> (Madras), <i>Safed chambeli</i> (Punjab) |
| <i>J. humile</i> | <i>Zarad chambeli</i> (Punjab), <i>Peeli chambeli</i> (Punjab) |
| <i>J. pubescens</i> | <i>Kunda</i> (West Bengal & U.P.), <i>Kundo</i> (Bombay & Baroda) |
| <i>J. sambac</i> | <i>Bacful</i> (West Bengal), <i>Mogri</i> (Bombay & Baroda), <i>Malligai</i> , <i>Malle</i> (Madras), <i>Motia</i> (Punjab), <i>Moghra</i> (U.P.) |

TABLE 12—PROPERTIES OF JASMINE CONCRETE AND ABSOLUTE*

| | Concrete of extraction | | Absolute of extraction | |
|------------------------|------------------------|---------------------------|------------------------|-------------------------|
| Congeaing pt, °C | 47-51 | .. | .. | .. |
| m.p., °C | 49-52 | 47-52 | .. | .. |
| Sp. gr. | .. | 0.866-0.8987 (60°/60°) | 0.962 (min.) (15°) | 0.929-0.955 (20°/4°) |
| [α] _D | +45 to +12 | .. | .. | +2° 23' to 4° 95' |
| n _D | .. | 1.4640-1.4658 | 1.4860-1.4920 (20°) | 1.4822-1.4935 (20°) |
| Acid val. | 9.8-12.6 | 12.6-15.4 | 25-30 | 4.2-17.6 |
| Ester val. | 68-105 | .. | 124-194 | 96.4-147.6 |
| Benzyl benzoate, % | .. | .. | .. | 4.5-8.5 |
| Indole, % | .. | .. | .. | 0.08-0.20 |
| Methyl anthranilate, % | .. | .. | .. | 0.15-0.35 |

* Guenther, V, 327-28

The bulk of the harvested flowers is used as such for religious offerings, garlands and decorations; a portion is used for the production of hair oils and attars.

Scented hair oil is prepared in the eastern districts of Uttar Pradesh (Ghazipur, Jaunpur, Kanauj, and Sinkandarpur) by a modified enfleurage process. Husked sesamum seeds and jasmine flowers are spread in alternate layers on the floor of a cemented pit and left exposed to the sun. The flowers are replaced every day with fresh ones, the process being repeated for a month or two. During the operation the seeds get impregnated with the essential oil of jasmine. Perfumed oil is extracted from the seed in country *ghanies*. For the preparation of jasmine attar, the flowers (*Jasminum sambac*, *J. grandiflorum*, and *J. auriculatum*) are distilled directly without using steam in earthenware vessels and the perfumed vapours absorbed in sandalwood oil. About 10 lb. of sandalwood oil are used for absorbing the perfume principles from 500-700 lb. of flowers. A superior grade of attar is obtained by aging the product for 3-4 years; during the period of storage, fresh jasmine extract is added every year.

Work on the extraction of jasmine flower oil has been recently undertaken in India at the instance of the Essential Oils Committee of the Council of Scientific and Industrial Research. Flowers from different species of *Jasminum* and from different areas have been examined. Flower oil was extracted by the enfleurage process using mutton tallow and absolutes were prepared from the pomades obtained. The highest yield of absolute, 0.2646%, was obtained from *J. grandiflorum*.

Properties—Jasmine concrete obtained by solvent extraction is a reddish-brown waxy mass, partly soluble in 95% alcohol, with a characteristic jasmine flower odour. Freshly prepared

TABLE 13—PROPERTIES OF STEAM-DISTILLED OIL FROM CONCRETES & ABSOLUTES*

| | | | |
|------------------------------|--------------------|--------------------------|--------------------|
| Sp. gr. ^{1a} | 0.988-1.004 | 0.966-1.0106 (20°/4°) | 0.993-1.047 |
| [α] _D | -0° 40' to +3° 30' | -2° 64' to +3° 18' | +2° 10' to +3° 40' |
| n _D ^{2a} | 1.4938-1.4982 | 1.4920-1.5041 | 1.4944-1.5015 |
| Acid val. | 2.24-3.50 | 0.1-6.7 | 2.2-7.5 |
| Ester val. | 193.0-224.2 | 165-227 | 234.0-268.8 |
| Indole, % | .. | 0.10-0.31 | .. |
| Methyl anthranilate, % | .. | 0.22-0.40 | .. |

* Guenther, V, 330, 333

1, Oils from concretes of French origin (Grasse);
2, oils from absolutes of extraction; 3, oils from absolutes of enfleurage

jasmine absolute (solvent extraction) is a viscous, clear, yellow-brown liquid with a delightful fragrance characteristic of the fresh flowers. It is soluble in 95% alcohol. The absolute darkens on aging, becomes turbid, and a grayish deposit separates. The odour deepens and the colour changes to red. The absolute obtained by the enfleurage process is a viscous oil of dark reddish brown colour soluble in 95% alcohol. On aging the colour changes to dark red and a deposit separates out; the solubility in alcohol is affected. The absolute has the odour of live flowers with a fatty off-note, the latter becoming more pronounced with age (Guenther, V, 327-32).

Table 12 gives the properties of jasmine concrete and absolute prepared by the solvent extraction process. The characteristics of absolutes prepared by the enfleurage process depend on the procedure adopted in the preparation and purification. Table 13 gives the properties of volatile oils obtained

TABLE 14—PROPERTIES OF INDIAN JASMINE OIL

| | <i>J. grandiflorum</i> * (from absolute of enfleurage) | <i>J. auriculatum</i> † |
|--|--|-------------------------|
| Sp. gr. | 0.9814 (20°) | 0.9548 (30°) |
| [α] _D ^{20°} | +4.2628° | .. |
| $n_D^{20°}$ | 1.497 | 1.5185 |
| Sap. val. | 278.06 | 140.04 |
| Acid. val. | 1.16 | 7.2 |
| Ester val. | .. | 132.84 |
| Concrete content, % | .. | 0.412 |
| Absolute content, % | .. | 0.146 |

* Dhingra et al., *Indian Soap J.*, 1951, 16, 259† Gupta et al., *Perfum. essent. Oil Rec.*, 1941, 42, 369

from absolutes and concentrates by steam distillation. Table 14 gives the characteristics of Indian jasmine oil.

Jasmine flower is reported to contain benzyl acetate (chief constituent), linalyl acetate, benzyl benzoate, benzyl alcohol, geraniol, nerol, *l*- α -terpineol, *l*- and *dl*-linalool, farnesol, nerolidol, eugenol, *p*-cresol, cresol, benzaldehyde, jasmone, benzoic acid, methyl anthranilate, and indole (Guenther, V, 325, 37).

Uses—Jasmine oil is used in high grade perfumes. The absolutes, although expensive, give the best results. Some perfumers in France purchase concretes and prepare alcoholic washings for use in handkerchief perfumes.

Khus Oil

Khus oil is a thick viscid liquid, yellowish to dark brown in colour, with an intense and persistent odour. It is obtained from the roots of *Vetiveria zizanioides*, a densely tufted, perennial grass, 3–6 ft. high. The grass is widely distributed in both hemispheres. In India it is found throughout the plains and lower hills, up to an altitude of 4,000 ft. It thrives well in a warm, damp climate and is particularly abundant on the banks of rivers and rich marshy soils. The grass is found wild in Uttar Pradesh, Punjab, Bharatpur, and parts of Ajmer. It grows more or less wild also in Assam, Bihar, Orissa, Hyderabad, and Mysore. In Madhya Pradesh it is met with partly wild and partly cultivated. It is cultivated as a crop in parts of Madras State, particularly in South Malabar, Tuticorin, East Godavari and Kurnool, and in South Travancore. The estimated acreage distribution under khus in different parts of India is as follows: U.P., 2,325; Punjab, 1,250; Bharatpur, 6,000; Madras State and South Travancore, 750. The estimated output of roots from the various regions is as follows: U.P., 26,500; Punjab, 16,000;

Bharatpur, 20,000; Madras State and South Travancore, 15,000 md.

There are apparently two varieties of the grass—one flowering and the other non-flowering. Khus growing wild in N. India is mostly the flowering variety. Both varieties are found in S. India (Menon & Ittyachan, *Survey of Indian Vetiver (Khus) & Its Oil*, C.S.I.R. Monograph, 1945, 6).

Khus roots vary in colour from light yellow or yellowish brown to reddish. They vary in length from 4 to 14 in. and in thickness from 1 to 3 mm. Thicker roots yield more oil than thin ones. Only mature roots, which are long, fleshy, and hairy, should be harvested for the production of oil. The usual practice in N. India is to dig out the roots at intervals of two years or more. The harvesting starts in December and continues up to February.

Bharatpur is the biggest centre of khus oil distillation in N. India. Other centres of production are Biswan, Musanagar, Nawabganj, and Utripara in U.P. The industry is managed by a few firms of Kanauj who send out oil extraction parties during the season to various centres to carry out the distillation. These firms own and operate in all about 500 distillation units, one firm alone operating 140 units in Bharatpur for distilling 400 tons of roots. In South India, distillation is carried out in Cochin with roots collected from Trivandrum, Tuticorin, Tinnevely, and Charghat (South Malabar).

Distillation—The oil is recovered from khus roots by steam distillation using copper stills. The roots are cleaned and steeped in water for 12–16 hours. Chopped pieces, 2–4 in. long, are charged into the still along with the aqueous distillate from the previous distillation (60–70 lb. of distillate to 1 md. of root cuttings). The still is closed with a lid and rendered steam-tight by applying clay. The still is heated over low fire in the beginning, the intensity of heat being increased towards the close of the distillation. The distillation is continued till 60–70 lb. of distillate are collected in the receiver. The delivery tube is removed and about 60 lb. of distillate from the previous batch are added to the still; distillation is resumed and a second batch 50–60 lb. of aqueous distillate collected; the addition of aqueous distillate to the still and redistillation of the charge are repeated next day after allowing the still to cool during the night. At the end of the third distillation, the total period of distillation being 11–12 hr., the distillate (150–180 lb.) is transferred to a tank and the oil floating on the surface is ladled out into a receptacle. The oil sticking to the bottom and the walls of the receiver is collected with the help of a stick (4 ft. long) with strings (6 in. long) tied at one end. The oil soaks into the strings and is wrung out. The oil collected in the receptacle is in the form of an emulsion which is broken by the

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addition of common salt. The clear oil which floats on the surface still contains dust particles and traces of water and these separate on storing the oil for 2-3 months.

Modern stills using low pressure steam have been set up by Messrs. *Manuan Lal Ram Narain* of Kanauj. Messrs. *Gas & Metal Operators*, Kanpur have recently installed improved stills with false bottoms. The duration of distillation for oil recovery is 24-36 hours and the yield of oil is 25-30% above that obtained in primitive stills.

Yield of oil—The yield of oil depends on the quality and maturity of roots. The oil contents of roots collected from different centres in India are given in Table 15. Actual yields of oil by the primitive distillation method at various centres are given in Table 16. It has been observed that the oil content of roots from wild plants collected in N. India is lower than that of roots from cultivated plants in S. India. Further, the roots of the non-flowering variety are richer in oil than those of the flowering variety.

TABLE 15—OIL CONTENTS OF KHUS ROOTS FROM DIFFERENT AREAS*

| | Roots free from knots | Root knots | Remarks |
|------------|-----------------------|------------|-------------------------------|
| Daulatgarh | 0.63 | 0.05 | Flowering var. |
| Naswaria | 0.74 | .. | do. |
| Rupwas | 0.87 | 0.10 | do. |
| Math | 0.45 | 0.16 | do. |
| Mandhna | 0.73 | .. | do. |
| Musanagar | 0.42 | 0.08 | do. |
| Biswan | 0.85 | 0.18 | do. |
| Bharatpur | 1.25 | 0.06 | Non-flowering var. |
| Travancore | 2.07 | 0.22 | Reddish; free from dust |
| Ram Nagar | 0.25 | .. | Free from root knots and dust |
| Kanpur | 0.82 | .. | Free from dust |
| Uttaripura | 0.51 | .. | .. |

* Dhingra et al., *Indian Soap J.*, 1952, 18, 77

TABLE 16—YIELDS OF OIL FROM DIFFERENT PRODUCING CENTRES*

| | Yield per md (oz.) | Yield (%) |
|-------------------|--------------------|-----------|
| Sirsa | 2 | 0.15 |
| Bharatpur | 3 | 0.23 |
| Biswan | 2.5 | 0.19 |
| Gonda (Nawabganj) | 2.5 | 0.19 |
| Musanagar | 3 | 0.23 |
| Uttaripura | 3 | 0.23 |
| Kaipamangalam | 5 | 0.38 |
| Neyyapattinkarai | 6.5 | 0.50 |

* Menon & Ittyachan, *Survey of Indian Vetiver (Khus) and its Oil*, 27

TABLE 17—YIELDS OF KHUS OIL IN DIFFERENT COUNTRIES*

| | Av. yield % | Max. yield % |
|---------------|--|--------------|
| Java | 0.7-1.0 ^a 1.5-2.0 ^c | .. 3.0 |
| Reunion | 0.6-1.2 ^b 1.5-2.0 ^c | .. 2.0 |
| Brazil | 1.5-2.0 ^c | .. |
| Europe | 0.4-1.0 | .. |
| Haiti | 1.5-2.0 ^c | .. |
| India | | |
| Travancore | 0.5-1.7 | 2.0 |
| Malabar | 0.3 | .. |
| N. India | 0.1-0.3 | 1.2 |
| Belgian Congo | 1.1-2.0 | 2.9 |
| Jamaica | 1.2-3.3 | 4.0† |
| Philippines | 0.92 | .. |

* Dhingra et al., *Indian Soap J.*, 1952, 18, 77

^a Cottage industry; ^b primitive stills; ^c modern stills

† Using steam

Manuring and frequent irrigation of the crop are also important. The quality of the oil depends on the distillation period. The valuable aromatic constituents of the oil are recovered only by prolonged distillation.

The yields of oil from khus roots reported from various countries are recorded in Table 17. It will be seen that the yields reported from India are poor. Experimental distillation of roots grown in different parts of India employing improved methods indicate that higher yields, comparable with those in other countries, are obtainable from Indian khus roots (Puran Singh, *Chem. & Drugg.* 1914, 85, 225; Sudborough et al., *J. Indian Inst. Sci.*, 1925, 8A, 147; Nath, *Yearb. Dep. Agric. Madras*, 1918, 68; Dhingra et al., *Indian Soap J.*, 1952, 18, 77).

Properties and uses—Table 18 gives the analytical constants of oils from various sources. Table 19 gives the analytical characteristics of oils from different countries.

The principal constituents of khus oil are the isomeric ketones, α - and β -vetivones ($C_{15}H_{22}O$), which are responsible for the characteristic odour of the oil. Isomeric sesquiterpene alcohols (vetivenols or vetiverols, $C_{15}H_{24}O$), vetiveryl vetivenate, bicyclic and tricyclic sesquiterpenes, and benzoic acid are present.

The khus oil distilled in India is of varying consistency and colour. Oils distilled from dry roots in S. India are more viscid and have better aroma than oils distilled from fresh roots in N. India. Among the oils distilled in N. India, those from Musanagar and Bharatpur have better aroma, higher specific gravity (> 1), and higher ester and alcohol contents than others. The oil distilled at Bharatpur is reported to be

TABLE 18—ANALYTICAL CONSTANTS OF KHUS OIL FROM DIFFERENT SOURCES*

| | Sp. gr. ^{20°} | n | [α] | Sol. in 80% alcohol (vol.) | Acet. val. | Ester val. | Acid val. | Free vetiverol | Combined vetiverol |
|------------|------------------------|--------|---------|----------------------------------|------------|------------|-----------|-------------------|-----------------------|
| Sultanpur | 0.9951 | 1.5146 | — 88.4 | 1-2 | 8.6 | 19.4 | 168.9 | 63.54 | 7.77 |
| Biswan | 0.9848 | 1.5110 | — 91.9 | do. | 5.5 | 14.2 | 175.2 | 71.93 | 5.82 |
| Bharatpur | 1.0051 | 1.5140 | — 89.5 | do. | 8.5 | 24.6 | 197.7 | 78.10 | 9.80 |
| Math | 0.9970 | 1.5155 | — 120.8 | do. | 9.0 | 18.9 | 196.1 | 80.28 | 7.57 |
| Kanpur | 1.0467 | 1.5188 | — 74.2 | do. | 16.8 | 16.8 | 167.4 | 66.65 | 6.70 |
| Musanagar | 1.0476 | 1.5170 | .. | do. | 40.8 | 38.2 | 181.8 | 59.74 | 15.45 |
| Travancore | 0.9857 | 1.5190 | + 27.3 | 1-3 | 19.8 | 21.1 | 173.8 | 67.50 | 8.44 |

* Dhingra *et al.*, *Indian Soap J.*, 1952, 18, 77

TABLE 19—ANALYTICAL CONSTANTS OF KHUS OILS FROM DIFFERENT COUNTRIES*

| | Sp. gr. | | [α] | Acid val. | Ester val. | Acet. val. | Sol. in 80% alcohol |
|-------------|---------------|--------------|--------|-----------|------------|------------|---------------------------|
| Philippines | 1.0139 | | +30.08 | 21.5 | 6.5 | | |
| Java | 0.985-1.045 | 1.51-1.53 | +15-45 | 8-35 | 5-25 | 100-150 | 1-10 |
| Reunion | 0.99-1.02 | 1.515-1.529 | +14-37 | 4.5-17 | 5-20 | 119-145 | 1-2 |
| Haiti | 0.999-1.014 | 1.5198-1.525 | +22-31 | 7.5-16.8 | 8.4-52.3 | 124-164 | 1 |
| Brazil | 1.002 | 1.5244 | Dark | .. | 34.4 | 166.2 | |
| Jamaica | 0.9972 | 1.5243 | +17.3 | 15.5 | 10.6 | 117.9 | |
| Europe | 1.014-1.042 | 1.521-1.527 | +25-38 | 27-65 | 10-25 | .. | 1-2 |
| Malaya | 1.032 | 1.5240 | .. | 35.5 | 11.8 | 130-180 | .. |
| India | 0.9901-1.0486 | 1.5158-1.521 | —30.65 | 2.2-12 | 25-60 | 132-166 | 1-2 |

Dhingra *et al.*, *Indian Soap J.*, 1952, 18, 77

of the heavy type suitable for soap making, while the oil from Musanagar is said to be of a 'delicate' type suitable for perfumery. Indian oil is superior to those from Java and Reunion Island by virtue of its high vetiverol content (Dhingra *et al.*, *Indian Soap J.*, 1952, 18, 77; Narain *et al.*, *Indian Soap J.*, 1949, 14, 303).

Khus oil is adulterated with copaiba balsam oil and sometimes with castor oil. In recent years sandalwood oil is being used as adulterant.

Khus oil is widely used in perfumes, cosmetics, and soaps. It imparts a pleasing and lasting note to the perfume composition and serves as a fixative. It blends well with sandalwood, patchouli, and rose oils (Dhingra *et al.*, *Indian Soap J.*, 1952, 18, 77).

Concretes obtained by solvent extraction of roots contain the odorous principles in their entirety. Extraction *cum* distillation methods may be employed for the preparation of oil. Extraction by ether yields a brown resinoid with a persistent and agreeable odour in 5% yield. Esters of vetiverol have recently been marketed. Vetiveryl acetate is of value in compounding fancy floral and oriental perfumes. Vetiverol itself is a valuable fixative and gives character to many compositions. Synthetic oils of vetiver

TABLE 20—PRODUCTION OF KHUS OIL IN N. INDIA*

| | Roots distilled (md.) | Oil produced (lb.) |
|------------|--------------------------|-----------------------|
| Bharatpur | 15,000 | 2,812.5 |
| Biswan | 6,000 | 937.5 |
| Musanagar | 2,000 | 375.0 |
| Gonda | 4,000 | 625.0 |
| Uttaripura | 2,000 | 375.0 |
| Total | 29,000 | 5,125.0 |

* Menon & Ittyachan, *Survey of Indian Vetiver (Khus) and its Oil*, 41

have been marketed but are considered to be inferior to the genuine oil.

Production, uses, and trade—Table 20 gives the production of vetiver oil in N. India during 1943-44. About 25 lb. of oil are annually produced in South India.

There is practically no export market for the oil at present. About 80 lb. of oil were exported from Kanauj to Africa in 1945. Small quantities of oil are imported. Prior to World War II imports were mainly from Java and Reunion Island; during the war khus oil was imported from Europe and U.S.A. About 5,125 lb. of vetiver oil are consumed annually in India.

ESSENTIAL OILS

The estimated cost of production of oil in various centres, in 1946, was as follows: U.P., Rs. 104 per lb.; Bharatpur, Rs. 100-13-4 per lb.; and Punjab, Rs. 126 per lb. The present cost of production as calculated by Dhingra *et al.* is c. Rs. 110 per lb. The price of Indian vetiver oil in May 1952 was Rs. 130 per lb. [Menon & Ittyachan, *Survey of Indian Vetiver (Khus) and its Oil*, 30, 31; Moosad, *Madras agric. J.*, 1952, 39 (7), 403; *Perfum. essent. Oil Rec.*, 1952, 43 (5), 181].

Lemongrass Oil

East Indian Lemongrass Oil is derived from *Cymbopogon flexuosus* which is indigenous to India. The oil is valued on account of its high citral content (68-85%).

The principal constituent of both East Indian lemongrass oil and West Indian lemongrass oil (derived from *Cymbopogon citratus*, grown in gardens in Punjab, Bombay, and Baroda, but not exploited as a source of oil) is citral; the former oil is somewhat more soluble in 70% alcohol than the West Indian oil.

Among the essential oils produced in and exported from India, lemongrass oil ranks second in value, the first being sandalwood oil. *Cymbopogon flexuosus*, from which the oil is obtained, grows mainly in the northern districts of Travancore and in a small area in Cochin. Nearly half the total output of lemongrass oil from Travancore is produced in the northern parts of the State (Thodahpuzha, Vazhakolam, Moovatupuzha, Perambalur, and Alwaye).

The bulk of the oil is produced by distillation with water in crude direct-fired copper stills. The steam distillation method has been introduced in certain areas and an oil of light colour, rich in citral content is obtained. The grass, cut a few inches above the ground, either fresh or partially dried, is used for distillation. The still consists of a cylindrical vessel, 4 ft. high \times 2½ ft. diam., over which is placed a truncated cone, c. 1½ ft. high. The charge (c. 300-350 lb.) is introduced through a side opening in the cylinder and water is poured up to 10 in. below the side opening. The mixture of steam and volatile oil passes into a spiral condenser through a copper tube fixed to the cone and the condensed liquids are collected. The still is heated on an open wood fire and when steam begins to issue, 50-100 lb. or more of grass are introduced through the side opening which is then hermetically closed. Distillation is stopped when a test sample of the distillate is free from the oil. The distillation takes 3-3½ hours, and 4-5 distillations are carried out in a day.

The upper layer of the distillate collected in the receiver, constituting the oil, is ladled out and stored in glass, copper, or tin receptacles. An acre of land producing 15,000 lb. of grass per year gives a yield of about 30 bottles of oil, each

of 29½ oz. capacity (Information from Mr. N. S. Varier, Central Research Institute, University of Travancore, Trivandrum).

Properties—The oil is a reddish yellow to reddish brown, mobile liquid with an intense lemon odour and taste. The characteristics of the oil are as follows: sp. gr.^{15°}, 0.899-0.905; $[\alpha]_D^{20}$, -5° to $+1^\circ 35'$; n_D^{20} , 1.483-1.488; aldehyde content (bisulphite method), 70-85%, (neutral sulphite method, 65-80%); soluble in 1.5-3 vol. of 70% alcohol. The following constituents have been identified: methyl heptenone, dipentene, methyl heptenol, *n*-decylaldehyde, citral *a* and *b*, nerol, geraniol, and farnesol (Guenther, IV, 35). Table 21 gives the Indian standard for East Indian lemongrass oil.

A white-stemmed variety of lemongrass, designated *C. flexuosus forma albescens*, growing wild on the dry hill slopes of Travancore, gives an aromatic oil in 0.8% yield. The oil is insoluble in 70% alcohol and contains no citral. Oil distilled from lemongrass containing the white-stemmed variety in admixture is of poor quality due to its low citral content and low solubility in 70% alcohol. Efforts are being made to prevent the admixture of the grass with true lemongrass used in the production of commercial oil.

Kerosene oil, vegetable oils, and methylated spirit are sometimes used as adulterants of lemongrass oil. The presence of adulterants can be detected by determining the physical constants (Nair & Varier, *Indian Soap J.*, 1952, 17, 229).

The citral content of the oil decreases and the density increases during storage, the changes being influenced by the presence of moisture and by exposure to air. There is also a fall in the germicidal activity of the oil. Thus in one sample of commercial oil stored for 3½ years, the citral content decreased from 78% to 63% and the density increased from 0.89 to 0.925 g./cc. It is important, therefore, to dry the oil thoroughly and store it in air-tight containers. Ethyl or *n*-propyl gallate in conjunction with citric or tartaric acid may be used as antioxidant (Bose *et al.*, *J. sci. industr. Res.*, 1950, 9B, 37).

TABLE 21—INDIAN STANDARDS FOR LEMONGRASS OIL*

| Colour & appearance | Reddish yellow to brown, mobile liquid |
|---------------------|--|
| Odour | Lemon-like |
| Sp. gr. at 15°/15° | 0.900-0.910 |
| Sp. gr. at 25°/25° | 0.892-0.902 |
| Sp. gr. at 30°/30° | 0.888-0.898 |
| $[\alpha]_D^{20}$ | -3° to $+1^\circ$ |
| n_D^{25} | 1.4786-1.4846 |
| n_D^{30} | 1.4808-1.4868 |
| Citral, % by vol. | ≤ 75 |
| Solubility | Sol. in 70% alcohol |

* I. S. specification 327-1952

The bulk of the oil produced in India is exported from Cochin to Europe and America. The oil is brought for sale to Kothamangalam, Alwaye, and Moovathupuzha; the price is fixed by shippers on the basis of the citral content and solubility. Oils low in citral content are blended with rich oils and the citral content adjusted to 77% and packed in drums (400 lb. per drum) for export. The chief exporters and stockists are: (1) *Pierce Leslie & Sons*, Cochin; (2) *Volkart Brothers*, Cochin; (3) *Makkar Pillai & Co.* Alwaye; and (4) *Aspinwell & Co.*, Cochin.

Uses—Lemongrass oil is used for perfuming soaps and detergents; it is also used in disinfectants and germicidal preparations. It is employed as a source of citral for use in cosmetics and perfumery. Citral is also the starting material for ionone which is an important ingredient of synthetic violet perfumes. Many grades of ionones are now available in mixed and pure forms and their use enhances the perfumer's ability to produce every nuance of odour desired. β -Ionone has been employed as a starting material in the synthesis of vitamin A.

Citral is isolated from lemongrass oil by shaking it with sodium bisulphite solution. The crystalline reaction product is washed with alcohol and ether, citral regenerated by decomposition with sodium carbonate, and separated by distillation *in vacuo* (Guenther, III, 327).

The demand for lemongrass oil in India is rather limited, being confined to soap makers who consume only 5% of the output.

Production and trade—India is the world's principal producer of the oil. During World War II when supplies of oil were not readily available from India, production of West Indian lemongrass oil, derived from *C. citratus*, was started in Guatemala, Honduras, and Haiti. U.S.A., which is the principal market for lemongrass oil, was obtaining a large part of her requirements during the war from Haiti and Guatemala. The latter produced 190,542 lb. of oil in 1943 and 135,000 lb. in 1949. Haiti produced 33,422 kg. of oil in 1947-48 and 24,175 kg. in 1948-49. Honduras produced 50,000 lb. from 1942 to 1947 and Belgian Congo, 12 metric tons in 1949. Florida stopped production soon after the cessation of the war when the price of the oil per lb. dropped from \$4.00 to \$1.00.

Table 22 gives the estimated production of lemongrass oil in India. A target production of 700 tons of oil per year has been recommended by the Panel on Oils and Soaps (*Panel Rep., Oils & Soap Industries*, Govt. India, 26).

Table 23 gives the exports of lemongrass oil from India.

Guatemala is the chief competitor to India in the export market. As compared to 319,900 and 305,800 lb. of lemongrass oil exported to U.S.A.

TABLE 22—PRODUCTION OF LEMONGRASS OILS IN INDIA*

| | Qty (tons) |
|---------|---------------|
| 1919-20 | 9 |
| 1934-35 | 50 |
| 1943-44 | 200 |
| 1944-45 | 400 |
| 1945-46 | 500 |
| 1946-47 | 550 |
| 1947-48 | 350-400 |
| 1948-49 | 300+ |
| 1949-50 | 360+ |
| 1950-51 | 425-500+ |
| 1951-52 | 720+ |

* Relates to the distillation period, July-January

† Estimated quantity; *Schimmel Rep.*, 1946, 30; *Schimmel Rep.* 1947-48, 34; *Industry*, 1951, 42, 379

‡ Provisional, *Indian J. Pharm.*, 1952, 14, 138

TABLE 23—EXPORTS OF LEMONGRASS OIL

| | Qty (gal.) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1934/35-1938/39 (av.) | 90,213 | 9,18,226 |
| 1939/40-1943/44 (av.) | 84,078 | 16,66,843 |
| 1944-45 | 121,629 | 32,12,243 |
| 1945-46 | 150,790 | 70,13,862 |
| 1946-47 | 132,290 | 107,95,131 |
| 1947-48 | 84,053 | 36,56,595 |
| 1948-49 | 95,824 | 24,07,677 |
| 1949-50 | 88,223 | 46,62,338 |
| 1950-51 | 127,706 | 132,64,366 |
| 1951-52 | 122,469 | 149,00,224 |
| 1952-53 | 92,092 | 39,17,100 |

from India during 1947-48 and 1948-49, 130,000 and 142,300 lb. of oil were exported to U.S.A. from Guatemala during 1947 and 1948.

Prices—The pre-war (1939) prices of lemongrass oil in the London market varied from 1s. 6d. to 1s. 10d. per lb. The price rose to 23s. per lb. in March 1942 but fell to 12s.-13s. 6d. per lb. in March 1945. The prices became easy at 6s. 6d.-8s. per lb. in July 1947. In June 1950, the price was 12s. 6d.-14s. 6d. per lb. The price was 7s. 6d.-8s. 6d. per lb. in May 1953.

There has been a decline in the price of oil in the Cochin market. The quoted prices per case of 12 bottles (each containing 29½ oz. of oil) during 1950-52 were as follows: 1950, Rs. 152/8; 1951, Rs. 315/-; 1952, Rs. 125/-.

Linaloe Oil

Mexico is the original home of linaloe oil, derived from the heartwood and, to a small extent, from the berries of *Bursera*, particularly from *Bursera delpechiana* Poiss.

B. delpechiana was introduced into India about 30 years ago and a plantation was started in Tatguni, 11 miles from Bangalore. The estate

TABLE 24—CHARACTERISTICS OF LINALOE OILS*

| | Mysore oil | Mexican oil | |
|-----------------------------------|--|---|---|
| | | from wood | from seeds |
| Sp. gr. ^{15°} | 0.8885-0.8911 | 0.883-0.889 | 0.885-0.888 |
| [α] | -0°18' to +2°18' | -5°25' to -13°8' | +2°4' to +3°10' |
| n _D ^{20°} | 1.4600-1.4623 (25°) | 1.4587-1.4612 | 1.4641-1.4650 |
| Acid val. | .. | 0.8-2.7 | up to 3.1 |
| Ester content as linalyl acetate% | 31.5-44.1 | 14-27.1 | 13.9-18.6 |
| Sol. at 20° | Sol. in 1.5-2.5 vol. of 70% alcohol | Sol. in 4-5 vol. & more of 60% alcohol | Sol. in 5 vol. & more of 60% alcohol |

* Guenther, IV, 342, 337, 341

covers an area of 250 acres and the planted area is being systematically expanded and the whole estate is expected to be stocked with linaloe trees in the course of the next five years. Unlike the Mexican practice, the oil is obtained at Tatguni exclusively from the outer husks of the berries. The yield of oil is 18% as compared to 2.5-3.0% obtained from the wood in Mexico. The oil is known in the trade as Mysore Linaloe Oil and locally as Indian Lavender Oil.

Ripe berries are collected after they drop to the ground and dried in shade on perforated plates mounted in racks, with free circulation of air. The period of collection extends over a period of 2½ to 3 months. The shells are separated and subjected to steam distillation for which 3 plants have been set up on the estate. Six pounds of mature fruit yield about 1 lb. of dried shells.

Mysore linaloe oil is a light coloured mobile liquid with a lily tone. It resembles Bois-de-Rose Femelle Oil from French Guiana and Shu Oil of Japan. It has considerable depth and body and shows superior staying power as compared with ordinary linaloe oil. It can be used as a fixative in perfuming lily, lilac, lavender, linden blossom, cananga, ylang-ylang, and sweet pea soaps. It can also be employed in transparent soaps where coloration has to be avoided on keeping.

Table 24 gives the characteristics of Mysore Linaloe Oil obtained by steam distillation of the husks of berries. The characteristics of the Mexican oil are given for comparison.

The main constituent of Mexican wood oil is linalool (60-75%); other constituents are geraniol, terpineol, methyl heptenone, methyl heptenol, linalool monoxide, nerol, and probably sesquiterpenes, octylene and nonylene. Mexican seed oil closely resembles the wood oil in chemical composition except for the fact that the seed oil usually contains dextrorotatory linalool as the chief constituent. It is occasionally employed as adulterant for the wood oil. Mysore oil consists largely of linalyl acetate (35-44%), which is highly

valued by blenders of perfumes, other constituents identified in the Mysore oil are methyl heptenol (1.5%), linalool (47.7%), sesquiterpenes, waxes and resinous substances (8.0%). The Mysore oil differs from the Mexican oil in possessing a somewhat higher sp. gr., a lower ref. index, and a substantially higher ester content (Guenther, IV, 342).

The average annual production of oil from the Tatguni estate is 6,000-7,000 lb., out of which about 1,000 lb. are sold in the Indian market; the balance is exported, chiefly to London. The average price during normal times is 3-4 s. per lb.

Recently, the leaves of linaloe trees from Tatguni estate have been subjected to steam distillation and an oil with a tenacious sweet odour has been obtained in a yield of 0.15-0.25%. The oil has the following characteristics: sp.gr.^{15°}, 0.8978; n, 1.4581; [α], -8°41'; sap. val., 195.4; acid val., 2.1; esters as linalyl acetate, 67.67%; free alcohol as linalool, 2.16%. The oil is highly valued in perfumery on account of the high ester content. The distillation of leaves may not prove economical on account of the poor yield of oil. (Rao & Rao, *Perfum. essent. Oil Rec.*, 1946, 37, 312).

Palmarosa Oil

India is the principal source of supply of Palmarosa Oil, obtained from rosha grass (*Cymbopogon martini*, motia variety). The oil is also produced in Seychelles Islands and Java.

The important centres of production of palmarosa oil in India are Malghat, Ellichpur, Burhanpur, Betul, and Nimar in Madhya Pradesh; Khannad and Nasik divisions, Surat, Dangs, Panch Mahals, and Baroda in Bombay State; and Jhabua, Dhar, Alirajpur, and Barwani in Madhya Bharat. Small quantities of oil are produced in Uttar Pradesh and Hyderabad. Oil of excellent quality, with a total geraniol content of 90-95%, is produced in Malghat, Ellichpur, and Burhanpur.

Cymbopogon martini (motia variety) is a tall,

perennial, sweet-scented grass occurring in the drier localities, from Kashmir through Punjab hills to Almora, Garhwal, and Singbhum, and extending from Madhya Pradesh to Rajasthan, Bombay and South India.

Harvesting of grass and distillation—The grass areas are taken on lease from Forest Departments by village agents financed by merchants and oil dealers in Bombay. These agents procure distilling equipment and hire crews of grass cutters. The harvesting period is October-November. The mature grass is cut a few inches above the ground and subjected to distillation soon after. In Madhya Pradesh, the top one-third of the grass consisting of leaves and flower heads is cut during September-October, tied in bundles of c. 0.5 lb., and stacked for 10-25 days before distillation.

Distillation is carried out in stills of copper or iron (c. 150 gal.), usually erected on the banks of streams. Bundles of grass (c. 240 lb.) are charged into the still through the manhole and fresh water (c. 40 lb.) added to cover the material. The still is closed with a wooden plate and the joints sealed with mud paste. The vapours pass through a tube fixed to the lid, its long arm leading to a copper receiver immersed in the stream and held in position by a wooden framework. Distillation takes 4-5 hr. The oil collected in the receiver is skimmed off, filled into galvanized iron containers of 2-4 gal. capacity, and transported to the nearest village where the oil is separated from the water by decantation. The oil is finally filtered through cloth into containers or drums of 45 gal. and despatched to Bombay. Galvanized iron drums are used as containers for exporting the oil.

The yield varies from 0.12-1.39%. The flowering heads are rich in oil (1.71%); and stalks contain the least quantity (0.04%). The average yield of oil is 1% on the weight of sun-dried grass (moisture content, 28%) or 47 lb. per acre. A better quality of oil is obtained in higher yield (1.25% on sun-dried grass) by steam distillation. Equally good results are obtained by the use of improved direct-fired stills with false bottoms [Pearson, *Indian For. Rec.*, 1916, 5(7); Rao et al., *Indian Soap J.*, 1948, 14, 159].

Palmarosa oil is a pale yellow liquid with a characteristic geranium odour. The constants of the Indian oil vary within the following limits: sp. gr._{15°}, 0.887-0.900; n_{D}^{20} , 1.472-1.477; $[\alpha]_D$, -3° to $+6^\circ$ (usually $+1^\circ$ to -2°); acid val. 0.5-3.0; ester val., 12-48; ester val. after acetylation, 226-274; and total alcohol content calculated as geraniol, 74.8-94.8%; soluble in 1.5-3 vol. of 70% alcohol (Guenther, IV, 10).

Shipments of Indian palmarosa oil received and examined by *Fritzsche Brothers, Inc.*, New York, had properties varying within the following limits: sp. gr. _{15°}, 0.887-0.895; $[\alpha]_D$, $-1.34'$ to

$+2.45'$; n_{D}^{20} , 1.4730-1.4760; acid val., 0.7-1.1; ester content as geranyl acetate, 3.3-12.6%; total alcohol content as geraniol, 84-94%; soluble in 3-4 vol. and more of 60% alcohol (Guenther, IV, 10).

The values reported by Narain and Das Gupta are as follows: sp. gr., 0.886-0.889; $[\alpha]_D$, -3° to $+5^\circ$; n_{D}^{20} , 1.4720-1.4780; acid val., up to 3; ester val., 12-50; total geraniol content, 78-94%; soluble in 1-3 vol. of 70% alcohol. The oils from Hyderabad contain a higher percentage of esters (11-15% as geranyl acetate) than those from Madhya Pradesh (4.33-7.14% esters) (*Indian Soap J.*, 1948, 13, 259).

Palmarosa oil contains: formaldehyde, isovaleraldehyde, methyl heptenone, dipentene, citral, geraniol, geranyl acetate, geranyl *n*-caproate, and tarnesol (Guenther, IV, 16).

A common adulterant of palmarosa oil is ginger-grass oil (from the *sofia* variety of *C. martini*) which may be detected by the low total geraniol content of the adulterated sample. Other adulterants are: coconut, linseed or groundnut oil, turpentine oil, and kerosene oil.

Dealers in India evaluate the oil by shaking a test sample in a small bottle or by hitting the bottle containing the sample against the palm of the hand; the oil is assumed to be genuine if the air bubbles formed disappear quickly; if the air bubbles remain for some seconds and foam is formed, the oil is suspect. Exporters evaluate the oil by the solubility test, good solubility indicating high geraniol content (Guenther, I, 332; IV, 12).

The Seychelles oil resembles the Indian oil but its odour is somewhat soft. The Java oil is superior to the Indian oil; it has a soft, fruity, and rose-like character valued in perfumes and cosmetics. The Indian product is best suited for scenting soaps.

Uses—Palmarosa oil is used as a base for perfumes and in cosmetics, particularly in soaps, to impart a pronounced and lasting rose note. It is used also for flavouring tobacco. Along with sandalwood oil it forms an ingredient of mosquito repelling ointments. In medicine it is used externally as a remedy for lumbago, stiff joints, and skin diseases; it is reported to be used for baldness. It is given internally in small doses for bilious complaints. It is often used in India for adulterating attar of roses [Guenther, *Soap, N.Y.*, 1941, 17(8), 28; Pearson, *Indian For. Rec.*, 1916, (7)].

Palmarosa oil is the principal source of high grade geraniol. The oil is saponified with alcoholic sodium hydroxide and fractionally distilled in vacuum stills, the final distillate being geraniol (b.p., 230°). In the intermediate stages of distillation, a mixture of terpenes, suitable for use in soap

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TABLE 25—EXPORTS OF PALMAROSA OIL

| | Qty (gal.) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1934/35-1938/39 (av.) | 9,218 | 2,88,006 |
| 1938/39-1943/44 (av.) | 3,843 | 2,56,563 |
| 1944-45 | 7,061 | 12,10,883 |
| 1945-46 | 9,293 | 12,97,433 |
| 1946-47 | 3,802 | 7,19,438 |
| 1947-48 | 2,708 | 3,93,385 |
| 1948-49 | 7,950 | 10,05,473 |
| 1949-50 | 14,095 | 23,88,279 |
| 1950-51 | 18,515 | 39,49,263 |
| 1951-52 | 11,356 | 27,17,280 |
| 1952-53 | 15,843 | 20,83,608 |

blends, is obtained. Messrs. *Union Aromatics*, Bombay, produce c. 8,000 lb. of geraniol per season by this process.

Exports—Table 25 gives the exports of palmarosa oil from India. In 1945, U.S.A. imported 7,000 lb. of oil valued at \$45,370 and in 1946, 11,500 lb. valued at \$74,200.

Java exported 2,755 kg. of oil chiefly to England and Holland in 1937 and 4,721 kg. in 1938 (Guenther, IV, 13).

Prices—The pre-war (1939) price of palmarosa oil in the London market was 8s.-8s.1½d. per lb. During World War II the price of the oil rose to 60s. per lb. (1945). The price was 43s.6d.-47s.6d. per lb. in May, 1953. The price of palmarosa oil in the Indian market was Rs. 43 per gal. in 1939 and Rs. 140 per gal. in 1945.

Patchouli Oil

Patchouli oil is obtained from *Pogostemon patchouli* (syn. *P. cablin*), cultivated in Malaya, Sumatra, Java, Seychelles, Madagascar, Reunion Island, Paraguay, and Sao Paulo. About 90% of the world's output is obtained from Northern Sumatra.

Small quantities of patchouli oil are produced in India from leaves imported from Singapore. The distillation is carried out in a modern plant installed at the *Government Soap Factory*, Bangalore. During World War II, efforts were made to grow the plant in Mysore from cuttings obtained from Malaya (Rao & Rao, *Oil of Patchouli*, Bd sci. industr. Res., Mysore, 1945).

The quality of oil depends both on the leaf material and the method of distillation. It has been observed that the best leaf material is obtained from plants cultivated on rich soils. Only mature tops should be cut and the first two or three cuttings of a newly started plantation give good yields of high quality oil. The leaves should be dried without permitting fermentation to occur and the material for distillation should be freed from foreign matter and stalks. Storage of leaves appears to improve the quality of oil.

The distillation of leaves is best carried out by direct steam generated in a separate boiler. It is advisable to regulate the steam pressure and to alternate between low and high pressures. Both yield and quality are improved by prolonging the distillation. The more valuable components of the oil are apparently present in the higher boiling fractions. Aged oils—aged for several years—possess finer and fuller aroma than freshly distilled oils (Guenther, III, 564).

Properties and uses—Table 26 gives the physico-chemical characteristics of oils from indigenous and imported leaves distilled at the *Government Soap Factory*, Bangalore. Oils of good quality are characterized by high specific gravity, high laevo-rotation, high refractive index, and good solubility.

About 97% of the oil consists of compounds which have very little influence upon the odour. Of these, 40-45% belong to the sesquiterpene group; the rest consists of patchouli alcohol. The presence of the following constituents has been established: benzaldehyde, eugenol, cinnamic aldehyde, azulene, a sesquiterpene alcohol and

TABLE 26—CHARACTERISTICS OF PATCHOULI OILS DISTILLED AT BANGALORE*

| | Yield % | n_D^{20} | d_4^{15} | $[\alpha]_D^{20}$ | Acid val. | Ester val. | Acet. val. |
|---------------------|-------------------|------------|------------|-------------------|-----------|------------|------------|
| Bangalore† | 2.23 | 1.5201 | 1.0011 | -22.5° | 3.15 | 6.11 | 93.81 |
| Tjalong (Indonesia) | 1.93 | 1.5110 | 0.9941 | -35° | 2.25 | 6.75 | 24.80 |
| Tapa Toen (do.) | 2.22 | 1.5097 | 0.9858 | -48° | 2.88 | 2.37 | 23.25 |
| Menlobole (do.) | 3.66 | 1.5087 | 0.9817 | -48° | 2.76 | 3.47 | 18.94 |
| Johore (Malaya) | 4.04 | 1.5082 | 0.9707 | -38° | 1.85 | 3.12 | 17.60 |
| Singapore (do.) | 3.73‡ | 1.5106 | 0.9877 | -48.5° | 2.88 | 2.64 | 20.83 |
| Singapore (do.)* | 0.47 ^b | 1.5116 | 1.0097 | -48° | 29.40 | 4.05 | 49.90 |

* Schimmel Rep., 1945, 42

† Plants grown in the Govt. Soap Factory garden

‡ Av. of 22 distillations

* Leaf stems

^b Av. of 5 distillations

possibly another alcohol, 2 ketone bases, 2 sesquiterpenes, and patchouli alcohol.

Patchouli oil is one of the best fixatives for the heavy type of perfumes, such as amber, chypre, and fougere. It is useful in traces for compounding white rose bouquets. As a soap perfume it blends well with geranium, palmarosa, clove, khus, cassia, and other oils.

The oil is frequently adulterated with cedarwood oil.

The world production of patchouli oil is 75,000–90,000 lb. a year. During 1946 India imported 27.22 tons of patchouli leaves and 88.7 gal. of patchouli oil from Malaya (Schimmel Rep., 1946, 47).

Price—The price of patchouli oil was \$35 per lb. early in 1947. The price declined sharply and by the end of 1948 it was c. \$5 per lb. The price in May 1953 in the London market was 52s. 6d.–57s. 6d.

Rose Oil

Rose Oil of India, popularly called Otto of Rose, had once enjoyed high reputation in world markets for its quality. It was obtained from roses cultivated in Ghazipur near Banaras. At present, the Balkan countries are the biggest producers of rose oil of some of the finest qualities, the total annual production being 6,000–7,000 lb.

The chief centres of production of roses in India are Hathras, Sikandra Road, Hasayan, and Barwana in Aligarh district (U.P.). Rose oil is produced mainly at Barwana where the season for roses lasts only for six weeks—from the middle of March till the end of April. It is reported that during this period as much as 200 md. of rose petals are distilled per day; at the height of the season, which lasts for about a week, about 1,000 md. flowers are collected per day. The larger part of the harvested flowers is used for the production of rose attar. The distillation of rose oil is carried out in pot-stills by Kanauj distillers and the total production of Otto of Rose is reported to be 5–7 lb. The Essential Oil Advisory Committee has estimated that if all the rose petals in Barwana were used for the distillation of Otto of Rose and not of attar, the production can be raised, even by the present methods, to at least 50 lb. per annum. About 13,000 lb. of rose petals yield 1 lb. of rose oil in addition to rose water. The yield can be doubled by adopting improved methods of distillation [Gadre & Mukherji, *J. Indian Ind.*, 1922 2(1), 101].

Rosa damascena and other varieties of roses are cultivated in several places in South India, but not in quantities sufficient for the extraction of

oil. The Essential Oil Advisory Committee recommended that a systematic study of roses should be undertaken in Madras State to ascertain the possibility of producing rose oil. The Committee recommended also the extension of rose cultivation in India. The rose cultivation and problems connected with the rose oil industry in India has been examined by Dr. K. Biswas, Superintendent, Indian Botanic Gardens, Calcutta, under a scheme of research financed by the Council of Scientific & Industrial Research.

The price of rose oil from the Balkan countries ranges from Rs. 600 to Rs. 1,000 per lb. [*Rep. Essent. Oil Advisory Comm. (Exploratory)*, C.S.I.R. Monograph, 1946, 22].

Sandalwood Oil

Indian sandalwood oil, commonly known as East Indian Sandalwood Oil, is obtained from the roots and heartwood of *Santalum album*, an evergreen, hemiparasitic tree of the highland forests of Mysore, Coorg, and Bombay. The tree is also found in the Malayan Archipelago, particularly in the dry island of Timor. The oil differs in odour and composition from all other so-called sandalwood oils which are derived from entirely different plant families and genera.

Sandalwood and its oil have been used in India as perfumery materials since ancient times. Prior to World War I, sandalwood was being exported, mainly to Europe, and the distillation of the oil was being carried out by European perfumery concerns. The first modern sandalwood oil factory was established in India, at Bangalore, by the Government of Mysore during World War I. It was followed by the *Sandalwood Oil Factory*, Mysore, also belonging to the Mysore Government. The Bangalore factory was closed down after some time and the distillation of oil is now concentrated in the factory at Mysore. Other factories producing sandalwood oil on a small scale are: *Kangundi Industrial Works Ltd.*, Kuppam, *East Indian Sandalwood Oil Distilleries (India) Ltd.*, Kuppam, *South Indian Industrial Works Ltd.*, Kuppam, *Mettur Sandalwood Oil Co.*, Mettur Dam, *M. S. Sandalwood Oil Factory*, Kanauj, *National Sandalwood Distillery*, Kanauj, *Techno-Chemical Industries Ltd.*, Kozhikode (Calicut), and *Banga Luxmi Chemical Works*, Calcutta. More than 95% of the East Indian sandalwood oil is now produced in India, the Government factory at Mysore accounting for 75% of the total world's output. The Government of Mysore have arranged to get a portion of the sandalwood grown in the State distilled in New York, the oil being sold in U.S.A. and Canada (Sastry, *J. sci. industr. Res.*, 1944, 3, 75).

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Santalum album is a native of the highlands of southern India and the Malayan Archipelago. The bulk of the supplies of sandalwood comes from Mysore. The tree, which grows up to a height of 60-65 ft., attains full maturity at the age of 60-80 years. Under the forest laws strictly enforced in Mysore, only dead and dying trees can be cut, unless the trees show signs of the 'spike' disease. The laws in other States are less severe. Nevertheless, these valuable trees are never felled until they reach full maturity. Thanks to the planned reforestation programme of the Mysore Government, the future supplies of sandalwood are fully assured.

Mysore controls about seven-eighths of the world's production of sandalwood. Prior to World War I, the Government was auctioning through nine depots the major part of the sandalwood for export to foreign countries after reserving a small quantity for internal consumption—for religious purposes, for carving art ware, for burning as incense, and for distillation by the old water-distillation method. The bulk of the wood is now retained within the country for the production of oil. Madras and Coorg continue to sell wood at public auctions held periodically at Tirupatur, Satyamangalam, and Fraserpet.

The raw material for the distillation of oil consists of the roots and the heartwood of the sandal tree. Felled trees and roots are sawn to pieces, about 3 ft. long, debarked, and the sapwood removed without any waste of scented material. The raw material for distillation consists of roots, heartwood, and chips, the last containing both heartwood and sapwood. The yield of oil from roots is the highest, that from chips the lowest. The yield from billets varies from 4.5 to 6.25%. The average yield from 1 ton of material is 100-120 lb. of oil.

Distillation—The material is reduced to a coarse powder before charging into the stills. Chipping machines and disintegrators are employed for this purpose. In some of the factories the wood is chopped by hatchets and adzes and the chips fed into disintegrators. The particle size distribution in the powdered and sieved material should be such that when charged into the still the material forms a uniform porous body allowing the passage of steam over the entire mass.

The stills made of copper, rarely of iron, are designed to take a charge of $\frac{1}{2}$ -1 ton of powdered wood. The stills are greater in height than in diameter by about 25%. They are provided with goosenecks to conduct the vapours of oil and steam into tin-lined tubular condensers. The receivers are also tin-lined. The powdered material is placed on perforated false bottoms and a little space is left on the top of the burden.

The distillation is conducted with low pressure (20-40 lb./sq.in.) steam and is stopped when the yield of oil ceases to be economical, the time taken being 48-72 hr. The sandalwood oil floating on the surface of the distillate in the receiver is skimmed off with shallow ladles and collected in separating funnels. The water layer is drawn off and the crude oil stored in a separate vessel for some time when a little scum with suspended woody matter floats to the top. The oil is filtered, warmed again to drive out moisture, and filtered. The product is marketed as 'perfumery grade oil'. For obtaining oil conforming to pharmacopoeial standards, the oil is rectified, heated in vacuum stills to drive off the last traces of moisture, and filtered.

Properties—East Indian Sandalwood Oil is a yellowish, somewhat viscid liquid, with a characteristic 'heavy', sweet, and lasting odour. The chief constituent of the oil, amounting to 90% or more, is santalol, a mixture of two sesquiterpenes ($C_{15}H_{24}O$), α - and β -santalol of which the α -constituent predominates. The characteristic odour as well as the medicinal value of the oil is due to santalol. The higher the santalol content the greater the value of the oil. Oils of high quality contain 94% and even more of santalol. Other constituents reported to be present in the oil are: *iso*-valeraldehyde, santene, *l*-santenone, santenone alcohol, teresantalol, nortricycloekasantalol, santalone, α - and β -santalene, teresantallic acid, and santallic acid (Sastry, *J. sci. industr. Res.*, 1944, 3, 75) Table 27 gives the properties of the oil.

The following standard for East Indian sandalwood oil has been specified in the British Pharmacopoeia (1948): sp.gr.^{20°}, 0.971-0.983; $[\alpha]$, -15° to -20° ; n_D^{20} , 1.505-1.510; soluble in 5 parts of 70% alcohol at 20°; alcohols calculated as santalol

TABLE 27—PROPERTIES OF SANDALWOOD OIL

| | Mettur* | Mysore† |
|----------------------|-------------------------------------|----------------------------------|
| Sp. gr. | 0.978 (25°) | 0.9782 (15.5°) |
| <i>n</i> | 1.5058 (25°) | 1.5068 (20°) |
| $[\alpha]$ | -17.1° (25°) | -17.1° (20°) |
| Total santalol, % | 98.0 | .. |
| Free santalol, % | 91.0 | 91.2 |
| Ester of santalol, % | 5.0 | 2.5 |
| Solubility | Sol. in 5-12 vol. of 70% alcohol | Sol. in 5 vol. of 70% alcohol |

* Information from the Mettur Sandalwood Oil Company, Mettur Dam

† Sastry, *J. sci. industr. Res.*, 1944, 3, 75

($C_{15}H_{24}O$), 90%; and esters calculated as santalyl acetate ($C_{17}H_{26}O_2$), 2.0%. Indian standard specifications for the oil are as follows: colour, pale yellow or nearly colourless; odour and taste, characteristic, faint but persistent; sp.gr. $_{25}^{25}$, 0.965-0.980; sp.gr. $_{30}^{30}$, 0.962-0.976; $[\alpha]_D$, -15° to -20° ; n_D^{25} , 1.5010-1.5080; n_D^{30} , 1.4990-1.5060; ester as santalyl acetate ($C_{17}H_{26}O_2$), 2% (min.); free alcohols calculated as santalol, 90% (min.); and soluble in 5 vols. of 70% ethyl alcohol (B.P.C. 613; I.S. Specification No. 329, 1952).

Adulterants—Oils of cedarwood, guaiac wood, and West Indian, West Australian, and South African sandalwoods have been used as adulterants for East Indian sandalwood oil. Other substances reported to be used for the same purpose are: benzyl alcohol, castor oil, white paraffin oil, geraniol, and terpineol.

Uses—Sandalwood oil is used in medicine and in perfumery. Before the advent of sulpha drugs and antibiotics the major use for the oil was in the treatment of certain types of venereal diseases and chronic bronchitis. It is still used to a limited extent for these purposes. The oil is now used mostly in perfumery. It has excellent fixative properties and most compositions of the heavy and oriental type contain sandalwood oil. About 90% of the oil is consumed in the perfume, cosmetic, and soap industries.

Production—The average output of oil in the Sandalwood Oil Factory, Mysore, is about 120,000 lb. per year, the production capacity being 50% more. The output of all the other factories in India is about 40,000-50,000 lb. a year. The total annual production of sandalwood oil in India was 186,835 lb. in 1951 and 128,180 lb. in 1952.

Table 28 gives the production of oil in the Sandalwood Oil Factory, Mysore, during the past 10 years.

The oil is packed for export in standard tins, each containing 25 lb. net of oil. Other packings

TABLE 29—EXPORTS OF SANDALWOOD OIL

| | Qty (lb.) | Val. (Rs.) |
|-----------------------|--------------|---------------|
| 1934/35-1938/39 (av.) | 11,744 | 11,66,815 |
| 1939/40-1943/44 (av.) | 8,690 | 9,40,893 |
| 1944-45 | 26,096 | 7,57,041 |
| 1945-46 | 54,880 | 16,16,281 |
| 1946-47 | 77,198 | 25,13,875 |
| 1947-48 | 71,899 | 28,03,094 |
| 1948-49 | 31,019 | 10,97,229 |
| 1949-50 | 114,483 | 43,89,579 |
| 1950-51 | 209,928 | 73,31,801 |
| 1951-52 | 66,307 | 32,53,666 |
| 1952-53 | 125,098 | 48,57,938 |

recognized in the Indian market are: tins containing 5 and 10 lb.; aluminium bottles containing 1 lb., 8 oz., 4 oz., and 1 oz. For internal retail trade, 1 oz. containers are popular and 3-4 lakhs of such containers are annually used.

Export—Table 29 gives the exports of sandalwood oil from India. U.K., U.S.A., and Anglo-Egyptian Sudan are the chief importing countries.

Price—The basic price of sandalwood oil since 15 Jan. 1952 has been fixed at Rs. 46 per lb.

Turpentine

Oil of Turpentine is the volatile oil obtained from the oleoresin or the wood of some species of pines. From the point of view of volume of production, turpentine tops the list among essential oils, the world's annual production approximating to 50 million gallons. America is the largest producer. Considerable amounts are produced in France and Russia. Other producers are Spain, Portugal, Greece, Italy, Mexico, and India.

The *Pinus* species exploited in America for turpentine oil are *Pinus palustris* (longleaf pine) and *P. caribaea* (slash pine). French turpentine is obtained from *P. maritima* and Russian turpentine from *P. sylvestris*. Other species exploited are *P. pinea*, *P. helepensis*, *P. nigricans*, *P. austriaca*, *P. pinaster*, *P. laricio*, *P. alba*, and *P. ayacahuite*. *P. longifolia* is exploited in India as the source of turpentine. Some experimental work has been done on *P. excelsa* and *P. khasiya* which yield turpentine rich in a-pinene.

The raw material for the production of turpentine is the oleoresin which is obtained as an exudate from pine trees by wounding. Turpentine is also obtained by the steam distillation or destructive distillation of pine wood and as a by-product from the sulphate and sulphite liquors of wood pulp industry based on pine woods. The U.S. Federal Naval Stores Act recognizes four kinds of turpentine, viz. (1) gum spirits of turpentine obtained by the distillation of the oleoresin, (2) steam-distilled wood (S.D.W.)

TABLE 28—PRODUCTION OF SANDALWOOD OIL IN MYSORE*

| | Qty (lb.) |
|---------|--------------|
| 1941-42 | 205,318 |
| 1942-43 | 135,138 |
| 1943-44 | 79,492 |
| 1944-45 | 128,672 |
| 1945-46 | 171,639 |
| 1946-47 | 166,693 |
| 1947-48 | 138,558 |
| 1948-49 | 111,189 |
| 1949-50 | 117,035 |
| 1950-51 | 183,521 |

* Information from Government Sandalwood Oil Factory, Mysore

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turpentine, (3) destructively distilled (D.D.) wood turpentine, and (4) sulphate wood turpentine. Sulphite turpentine, obtained as a by-product from the manufacture of wood pulp by the sulphite process, is not officially recognized (Guenther, VI, 254).

Gum turpentine still forms the major part of the world's total production of turpentine, although wood turpentine is becoming more and more important, especially in U.S.A. Thus in 1947-48, out of the total of 464,814 barrels each 50 gal.), 260,345 barrels were made from wood and 204,469 barrels from gum. Out of 260,345 barrels of wood turpentine 158,918 barrels were produced by steam distillation, 98,687 barrels by sulphate process, and 2,740 barrels by destructive distillation. The amount of rosin produced from steam distillation of gum and wood were respectively 591,546 and 871,950 drums (each of 520 lb.). The by-products obtained were: pine oil, 113,633; pine tar, 79,275; rosin oil, 8,829; 'dipentene', 19,144; and other monocyclic hydrocarbons, 27,698 barrels (each 50 gallon) (Modern Chemical Processes, I, 149).

The oleoresin is obtained by repeated chipping or wounding of the tree. It exudes as a limpid liquid but on its way down the faced surface into the receptacle, some of it adheres, partially oxidizes, and accumulates as a comparatively dry resinous material called the 'scrape', which is poor in turpentine content. The flow of the resin can be stimulated by the application of solutions of strong acids and bases or of certain salts to the fresh wound. Acid stimulation by spraying 50% solution of sulphuric acid is being increasingly adopted in U.S.A. Not only is the rate of flow stimulated, but the flow at the accelerated rate is kept on continuously over a longer period than it would if the cut surface or 'streak' were not treated. With chemical stimulation, streaking may be done twice a month instead of once a week. Fungus stimulation, by spraying a spore suspension of the fungus, *Fusarium laterilium* f. *pini* on freshly chipped face, has also been shown to prolong the flow of gum from several pine species. Fungus stimulation is not in commercial use at present (Snow, *Econ. Bot.*, 1949, 3, 375; Guenther, VI, 265-67).

Steam distillation of gum oleoresin gives two commercial products, gum turpentine and gum rosin. The oleoresin is diluted with about one-third of its volume of turpentine, melted, strained through a screen (4-mesh) and filtered through cloth or filter paper coated with a filter aid, such as diatomaceous earth. In the Olustee method used in U.S.A., the thinned gum is washed with hot water to remove water-soluble impurities. On standing for some time, the water and gum separate and the water is drawn off. A little

oxalic acid is also added during the melting to remove stains due to iron rust. The cleaned gum is distilled either in 'fire stills' or in batch stills. The fire still consists of a large copper kettle heated directly by wood or oil fire. The turpentine is distilled off and separated by gravity. The rosin remaining in the kettle is removed while hot and strained through wire strainers. The batch still consists of a cylindrical tank into which cleaned gum is charged. The gum is heated by steam coils and sparged with live steam. The mixture of water and turpentine vapours is passed through a dephlegmator, then through a vapour chamber to separate entrained rosin acids, and then through tubular condensers. The turpentine in the distillate is separated from water by gravity and dehydrated by passing it through rock salt. The tailings and foreruns of the distillate are separated and used for diluting the oleoresin. Only the 'heart cut' is dehydrated and sent to storage for marketing (Modern Chemical Processes, I, 150; Guenther, VI, 267-71).

A continuous distillation process has been recently introduced in U.S.A. Oleoresin (turpentine, 30-40%) cleaned by the Olustee method is preheated to about 350°F. and sprayed into a flash chamber when about 70-80% of the turpentine is removed. The rosin flows down through a steam-jacketed column where it is stripped of the remaining turpentine by a current of live steam. The turpentine is removed continuously to a condenser, then to a decanter, where it is separated from the water. The rosin is removed continuously from the bottom of the still (Modern Chemical Processes, I, 152).

The advantages of the continuous process over the batch distillation process are: (1) lower capital investment; (2) 50% reduction in steam consumption; (3) less labour; (4) smaller floor space of the plant; and (5) small operating load. The last factor is important as only about 5 minutes throughput time is required for the rosin to pass through the processing, ensuring a better and more uniform quality of both turpentine and rosin (Modern Chemical Processes, I, 154).

Steam-distilled wood turpentine is produced by steaming shredded pine stumps and knots to remove the bulk of the volatile oil; the residual oil is extracted counter-currently with a volatile solvent, such as petroleum naphtha. In a more recent method of processing, initial steaming is omitted and the wood is solvent extracted, spent chips being steamed to recover the solvent. The extract is distilled to separate the volatile matter from the rosin. The volatiles are fractionated into turpentine, 'dipentene', other monocyclic hydrocarbons, pine oil, and the solvent by distillation in vacuum (Guenther, VI, 293-4).

Destructively distilled wood turpentine is produced by retorting pine stumps and top wood cut

TABLE 30—CHARACTERISTICS OF COMMERCIAL TURPENTINES*

| | Sp. gr. ¹⁵ | [α] | n _D ²⁰ | Boiling point (°C) |
|--|-----------------------|-------------------|------------------------------|-----------------------|
| American, from crude gum of medium quality | 0.8670 (20°) | −18.8" | 1.4690 | 155.0 |
| American, from crude gum of poor quality | 0.8695 (20°) | −21.6" | 1.4735 | 155.5 |
| Newport S.D.W. | 0.860-0.864 | .. | 1.4660-1.4675 | 154.0 |
| Hercules S.D.W. | 0.860-0.866 | .. | 1.465-1.469 | 150-158 |
| Aleppo pine oil spirits | 0.8543-0.8568 | +46.00° to +46.6° | 1.4638-1.464 | 155-158 |
| Algerian | 0.8543-0.8546 | +46.2° to +46.8° | 1.4636-1.4638 | 155-156 |
| Austrian | 0.863-0.870 | −39°10' to 36°30' | 1.46905-1.47033 | .. |
| French, from crude gum of medium quality | 0.8700 | −34.1° | 1.4714 | 154.8 |
| French, from crude gum of poor quality | 0.8730 | −34.2° | 1.4725 | 154.8 |
| Greek | 0.8605-0.8660 | +34° to +41° | 1.465-1.474 | .. |
| Russian | 0.862-0.872 | +3° to +20° | 1.470-1.475 | 156-171 |
| Sicilian | 0.856-0.863 | +25° | 1.4464-1.4681 | .. |
| Spanish | 0.865-0.875 | −29° to −23° | 1.4805 | 155-156 |
| Venetian | 0.865-0.878 | 8°15' to −11° | 1.46924 | .. |

* Mellan, 296

to proper lengths (20-36 in.). The wood is heated to the point of carbonization, and the vapours and tars are condensed. The distillate is distilled and fractionated to obtain turpentine. This method yields no rosin, but rosin spirits, pine tar oils, creosote oils, pine oils, pine tars, and charcoal are obtained as by-products.

Sulphate wood turpentine is obtained as a by-product in the manufacture of paper pulp from pine wood by the alkaline sulphate method. The vapours escaping from the digesters during the cooking process are condensed and the oily layer separated and rectified. It is necessary to eliminate the sulphur compounds by oxidation, e.g. by alkaline hypochlorite. The process does not yield rosin, but a liquid product, Tallol, is obtained by acidifying the digested liquid. When dehydrated and clarified, this product contains 40-45% rosin acids.

Table 30 gives a few characteristics of turpentines from various sources.

THE INDIAN INDUSTRY

Turpentine oil is obtained in India by the steam-distillation of oleoresin from *Pinus longifolia* (chir pine). Other species of pine, such as *P. excelsa*, *P. gerardiana*, and *P. khasiya*, occur in India. The first two species yield turpentine rich in α-pinene, but occur in inaccessible regions. *P. khasiya* yields an oil midway between American turpentine and Indian turpentine in quality, but it has not been exploited so far. A profitable source of turpentine in India is the oleoresin from *Boswellia serrata*, known as Indian Olibanum or Indian Frankincense, but it is not being utilized for this purpose.

Experimental trials on the production of turpentine and rosin, utilizing the oleoresins from the

expansive pine forests of Kumaon (U.P.) were first started in 1890. Tapping operations were started in 1890. Tapping operations were started in 1896 in the Nainital forest division and two distillation units, one in Nainital and the other in Nurpur, were started in 1896 and 1899 respectively. Large-scale production was started at Jallo, now in Pakistan, in 1915. The second factory was started in 1920 at Clutterbuckganj near Bareilly by the U.P. Forest Department. It was taken over in 1923 by a private company, The Indian Turpentine & Rosin Co. Ltd., in which the U.P. Government is a shareholder. The Forest Department undertakes the extraction of oleoresin and sells it to the company. The Government Rosin & Turpentine Factory, Miransahib, Jammu and Kashmir (distilling capacity, 90,000 md. of crude resin per year) was started in 1939 and the Rosin & Turpentine Factory, Nahan, Himachal Pradesh (distilling capacity, 70,000 md. of crude resin per year) in 1948. In addition to these, there are several privately owned small factories located at Hoshiarpur, Someshwar, Bhowali, Rishikesh, and Bareilly.

Raw material—*Pinus longifolia* grows abundantly in the sub-montane regions of the Himalayas up to an altitude of 5,000 ft. above sea level. The pine-belt of the Indian Union covers approximately 2,092,550 acres. *P. longifolia* is the only species tapped at present for the production of turpentine and rosin.

The approximate annual supplies of oleoresin from the different forests are given in Table 31.

Tapping—Details relating to the methods employed, the tools required, and the collection of oleoresin have been described by Marriott. The French 'cup and lip' method of tapping is employed for tapping in the Kumaon circle (U. P.) and other chir areas under the control of

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TABLE 31—OLEORESIN SUPPLIES FROM INDIAN FORESTS*

| | Qty (md.) |
|--|--------------|
| Muzaffarabad and Mirpur Divisions (Jammu & Kashmir) | 10,000 |
| Udhampur and Kathia (Jammu & Kashmir) | 50,000 |
| Kangra Division (Punjab) | 50,000 |
| Hoshiarpur (Punjab) | 50,000 |
| Simla hills (Punjab) | 40,000 |
| Tehri-Garhwal (U.P.) | 10,000 |
| Other U. P. forests and Kumaon hills | 150,000 |

Information from Mr. J. P. Taimini, *Jallo Subsidiary Industries Co. (India) Ltd.*, Lucknow

the Forest Department. The resin flows out when a blaze or channel is cut in the sapwood. When a tree is to be tapped for the first time, a cut is made in the base of the selected tree with a scribe to indicate the position for the channel. The outer bark is removed and with the help of a mallet and a chisel, a cut is made, about 8 in. broad, at a height of about 6 in. from the ground for inserting the lip. In the case of trees which have been tapped in the previous year, the lip is fixed at a point 4 in. below the top of the previous year's channel. The channel (6 in. long, $3\frac{3}{4}$ in. broad, and $\frac{3}{4}$ in. deep) is then made with an adze commencing about $1\frac{1}{2}$ in. above the chisel cut. The general practice is to make the channels perpendicular even on trees which are bent or twisted. Loose bark above and alongside the channel is removed by rubbing with the side of an adze so that the bark may not flake off and fall into the pot. Deep cutting into the bark during this operation is not done, except over a length of 6 in. above the top of the channel and a width of 5 in. where the channel is to proceed during the year; the excess thickness of bark in this case is chipped off with an adze to leave only a thickness of $\frac{1}{4}$ in. of bark. The lip is then inserted in the chisel cut and nails are fixed about 1 in. below the lip for hanging the receptacle made of unglazed clay in such a way that all the resin will flow into it. Lids are placed on the pots as they are hung. Only one channel is made in trees $3\frac{1}{2}$ –7 ft. in girth and two channels, $4\frac{1}{2}$ in. apart, in the case of larger trees (Marriott, *Bull. U.P. For. Dep.*, No. 9, 1936; Trotter, 1940, 328).

During the tapping period the channel is freshened periodically by removing with an adze a thin shaving of wood from it so as to open out clogged resin ducts. Freshening commences not later than March and from five to eight freshenings are made per month up to about the first week of November. The channel is not lengthened upwards more than $\frac{1}{2}$ in. at each freshening. The shaving should rapidly taper off in thickness and should be continued up to a length of about 6 in. and not down to the lip. The face of the channel

above the lip and the lip itself are kept clean and smooth. The depth of the channel should not exceed 1 in. The channel reaches a height of about 2 ft. at the end of the first year's work, and this is increased by about 18 in. each succeeding year. By the beginning of the fifth year the height of the channel will be such that the tapper will be required to carry a light ladder from tree to tree to enable him to reach high enough for the freshening operation. After 5 years a new channel is made $4\frac{1}{2}$ in. to the left of the first channel and this is tapped for 5 years. At the end of the second 5 years another new channel is again made $4\frac{1}{2}$ in. to the left, and so on, till tapping has proceeded right round the tree. In the subsequent period, channels are started on the inter-channel spaces of $4\frac{1}{2}$ in. The same method is adopted when two channels are used. No rest is therefore given to the tree which is always kept under tapping. This system of tapping is known as 'Light Continuous Tapping'.

About 5 years before the tree is due to be felled, 'heavy tapping' by cutting as many channels as possible with 2 in. space between them is adopted and this continues for about 5 years unless the tree dies sooner. The depth of channels in heavy tapping should not exceed 2 inches.

Under the tapping system adopted by the U.P. Forest Department, no harm has been observed to standing trees or to the forests. Adequate measures have been adopted for protecting resin-tapped forests against fire damage and this has resulted in stimulating chir regeneration.

The crude resin collected from the trees is strained and filled into tin containers holding not less than 40 lb. net and sent to forest depots, where improperly strained resin is strained, containers properly filled, sealed, and sent to the factory. Table 32 gives the production of crude resin in the Kumaon circle.

TABLE 32—PRODUCTION OF CRUDE RESIN FROM U.P. FORESTS*

| | Qty (md.) |
|-----------------------|--------------|
| 1930/31-1934/35 (av.) | 84,705 |
| 1935/36-1939/40 (av.) | 87,989 |
| 1940-41 | 106,296 |
| 1941-42 | 116,786 |
| 1942-43 | 93,369 |
| 1943-44 | 120,065 |
| 1944-45 | 149,185 |
| 1945-46 | 152,627 |
| 1946-47 | 102,872 |
| 1947-48 | 108,018 |
| 1948-49 | 133,762 |
| 1949-50 | 145,644 |

* Information from the Conservator of Forests, Kumaon Circle (U.P.)

Manufacture—The crude resin is emptied into a steam-jacketed melter provided with spiral mixers. Sufficient turpentine is added to the charge and the steam turned on. The contents of the melter are thoroughly mixed and the charge allowed to cool. Chips and other light impurities float to the top and heavy impurities, such as sand and water, settle at the bottom.

The clean resin is drawn off into storage tanks. The sludge and chips are returned to the melter for further extraction of resin. The clean resin is drawn off into storage tanks where silt, sand, etc., which settle at the bottom, are removed.

The refined resin is drawn into a steam-jacketed cylindrical charger by gravity from which it is transferred to the distillation still. Both steam-jacketed and vacuum stills are in use.

The resin is heated in the jacketed still to steam temperature and steam at low pressure is injected directly into the resin. The steam pressure is gradually increased as distillation proceeds. The vapours are passed through condensers and the distillate is collected in vessels with outlet

pipes and the turpentine which collects in the top layer drawn off, passed through lime water to remove rosin acids, and transferred to storage tanks. The turpentine is rectified and fractionated into light (grade I) and heavy (grade II) grades. The residue comprising the least volatile fraction of the oil remaining in the still is sold as Turpentine Grade III. The first two grades consist chiefly of pinenes, while Grade III oil is rich in sesquiterpenes. The various grades are dehydrated with common salt and anhydrous sodium sulphate. The dehydrated products are stored in tanks when the water still remaining settles at the bottom and is drawn off. The oils are next tested and packed into 5-gallon drums and 42-gallon barrels for the market.

Two grades of turpentine are marketed by the *Indian Turpentine & Rosin Co. Ltd.*, Clutterbuckganj, Bareilly—No. 1 quality and commercial quality. The bulk of the turpentine produced is No. 1 quality; the quantity of commercial grade turpentine does not exceed 15%. Four grades of turpentine are produced in the *Government*



Indian Turpentine & Rosin Co. Ltd., Bareilly

FIG. 89—STEAM-JACKETED IRON MELTERS FOR REFINING PINE GUM



Indian Turpentine & Rosin Co. Ltd., Bareilly

FIG. 90—A BATTERY OF DISTILLATION STILLS

Rosin & Turpentine Factory, Miransahib (Jammu and Kashmir) and three in the *Himachal Rosin and Turpentine Factory*, Nahan (Himachal Pradesh). The properties of the different grades are indicated in Table 33.

Properties—Rectified oil of turpentine obtained from *Pinus longifolia* is a colourless, limpid liquid, with a strong characteristic odour and a pungent, somewhat bitter taste, both of which become stronger and less pleasant on storage and on exposure to the air. It contains hydrocarbons, principally Δ^3 -carene. Other constituents are resin acids, camphene, polymerized terpenes, etc. Traces of oxidation products, such as formic, acetic, and camphoric acids are also present. The oil is optically active but different samples show variable amounts of optical rotation. The average percentage composition of the commercial oil is as follows: α -carene and α -d-terpenes, 37.6; α -l-terpene, 1.7; l-pinene, 24.8; β -pinene, 9.7; longifolene, 20.3%, and small quantities of silvestrene and dipentene (I.P.C., I, 192).

The characteristics of turpentine oil from *Pinus longifolia* are as follows: d_{30}^{30} , 0.8717; n_D^{30} , 1.4725; $[\alpha]_D^{25}$, -2.72° ; and acid val., 2.4. The values reported by Guha and Roy are: d_{22}^{22} , 0.8622; n_D^{27} , 1.4715; $[\alpha]_D^{25}$, -8.29° . The Indian Pharmaceutical Codex specifies the following standards: d_{15}^{15} , 0.860–0.870; n_D^{20} , 1.467–1.477; iod. val. < 280 (Verghese & Gulati, *J. sci. industr. Res.*, 1951, 10A, 112; I.P.C., I, 193).

The odour of the Indian turpentine oil is distinct from that of the American oil. It is considered inferior to the American product as it is oxidized easily and leaves a residue on evaporation. The oil is similar to the Russian turpentine oil in many respects.

Oil of turpentine is often adulterated with petroleum oil, resin oil, and wood turpentine.

Uses—Indian turpentine is suitable for use in varnishes, paints, lacquers, and disinfectants. Attempts have been recently made to prepare from the oil synthetic camphor, terpin hydrate, terpineol, p-cymene, and p-menthane, dipentene,

TABLE 33—PROPERTIES OF INDIAN TURPENTINE

| | Colour | sp. gr. | Non-volatile residue % | Distillation range |
|--|----------------|-------------------|------------------------|--------------------|
| <i>Indian Turpentine & Rosin Co. Ltd. :</i> | | | | |
| No. 1 quality | Colourless | > 0.860 (30°) | > 1.5 | 95° below 180° |
| Commercial quality | Straw pale | > 0.870 (30°) | > 2.5 | 85° below 180° |
| <i>Jammu Rosin & Turpentine Factory :</i> | | | | |
| I quality | Water white | 0.8640-0.8666 | .. | .. |
| II quality | do. | 0.8700-0.8800 | .. | .. |
| III refined | White | 0.8801-0.8900 | .. | .. |
| III ordinary | Reddish | 0.8901-0.9000 | .. | .. |
| <i>Himachal Rosin & Turpentine Factory :</i> | | | | |
| I quality | Water white | 0.855-0.860 (30°) | up to 1 | 95° below 180° |
| II quality | do. | 0.861-0.870 (30°) | up to 3 | 90° below 210° |
| III quality | Reddish yellow | 0.871-0.890 (30°) | up to 10 | above 250° |

polymerization and condensation products, pine oil, and insecticidal compositions [Guha & Roy, *J. Indign Inst. Sci.*, 1941, **23A**, 201, 208, 217; Bhushan *et al.*, *J. Indian chem. Soc. Industr. & News Ed.*, 1944, **7**(2), 62; Verghese, *J. sci. industr. Res.*, 1950, **9A**, 83; Bhushan & Sharma, *J. Indian chem. Soc. Industr. & News Ed.*, 1950, **13**(1), 29].

Recently peroxides from turpentine have been used as catalysts for the production of 'cold rubber'. Δ^3 -carene which is present in Indian turpentine is oxidized rapidly and gives good yields of peroxides. *p*-Cymene is also obtained in good yield from Indian turpentine (Sondhi, *Sci. & Cult.*, 1949-50, **15**, 202; Fisher *et al.*, *Industr. Engng Chem.*, 1951, **43**, 671).

A process has been developed for the production of myrcene from β -pinene, a component of gum turpentine. Myrcene is used as a substitute for butadiene or isoprene in the manufacture of rubber. When condensed with maleic anhydride or other dibasic acids it produces resins and polyhydric alcohols suitable for use in perfume bases [*Chemurg. Dig.*, 1950, **9**(11), 14].

Oil of turpentine from *Pinus longifolia* is included in the Indian Pharmaceutical Codex under the name *Oleum terebinthinae*. It is locally irritant and feebly antiseptic. It is absorbed by the mucous membranes of the alimentary canal and the respiratory tract. In small doses frequently repeated, it at first stimulates the kidneys, augmenting the secretion of urine. Most of the therapeutic uses of the oil may be attributed to its local irritant action. During its elimination through the mucous membrane of the lungs it acts as a stimulant expectorant and is a useful remedy in chronic bronchitis. As a carminative in flatulent colic, it is particularly valuable. In

typhoid fever it is useful not merely in tympanitic state for its carminative effect but appears to have a direct influence upon the disease itself. It is also used to arrest minor haemorrhages, as in a tooth socket or nose. In the form of enema the oil is useful in obstinate constipation, tympanitis, and scateworms. Externally, it is an excellent rubefacient and is widely employed in the form of liniments in various rheumatic affections, such as lumbago, arthritis, and neuralgia. In the form of turpentine stupe it is advantageously employed as a counter-irritant in various deep-seated inflammations, especially of the abdomen. The irritant properties of turpentine vapour have been taken advantage of in the treatment of chronic bronchitis; it is especially recommended in gangrene of the lungs (I.P.C., I, 192-93).

Production—Table 34 gives the production of turpentine in India.

Price—The price of turpentine from Nahan factory during 1949-50 varied between Rs. 2/- and

TABLE 34—PRODUCTION OF TURPENTINE*

| | Qty (lakh gals) |
|---------------|-----------------|
| 1944-46 (av.) | 5.00 |
| 1947 | 2.50 |
| 1948 | 5.49 |
| 1949 | 5.17 |
| 1950 | 4.73 |
| 1951 | 6.76 |
| 1952 | 5.72 |

* Information from the Development Wing, Ministry of Commerce & Industry, Govt. India

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TABLE 35—IMPORTS OF TURPENTINE AND TURPENTINE SUBSTITUTES

| | Turpentine | | Turpentine substitutes | | Total | |
|-----------------------|---------------|---------------|------------------------|---------------|---------------|---------------|
| | Qty (tons) | Val. (Rs.) | Qty (tons) | Val. (Rs.) | Qty (tons) | Val. (Rs.) |
| 1934/35-1938/39 (av.) | 183.2 | 82,506 | 983.9 | 2,48,679 | 1,167.1 | 3,31,185 |
| 1939/40-1943/44 (av.) | 668.0 | 1,40,518 | 2,932.7 | 4,64,266 | 3,600.7 | 6,04,784 |
| 1944-45 | 33.9 | 5,848 | 3,501.8 | 5,70,411 | 3,535.7 | 5,76,259 |
| 1945-46 | 63.3 | 9,600 | 7,746.2 | 9,17,510 | 7,809.5 | 9,27,110 |
| 1946-47 | 1,406.3 | 1,60,677 | 50.8 | 9,866 | 1,457.1 | 1,70,543 |
| 1947-48 | 6.1 | 6,854 | 1,936.2 | 2,09,770 | 1,942.3 | 2,16,624 |
| 1948-49 | 2,255.4 | 5,61,380 | 10.9 | 5,897 | 2,266.3 | 5,67,277 |
| 1949-50 | 3,871.2 | 4,57,530 | 737.5 | 96,041 | 4,608.7 | 5,53,571 |
| 1950-51 | 3,259.6 | 6,39,553 | 1,492.1 | 2,01,387 | 4,751.7 | 8,40,940 |
| 1951-52 | 2,188.7 | 4,61,041 | 2,136.3 | 4,73,941 | 4,325.0 | 9,34,982 |
| 1952-53 | 1,800.9 | 9,45,020 | 1,731.4 | 4,75,274 | 3,532.3 | 14,20,294 |

TABLE 36—EXPORTS OF TURPENTINE

| | Qty (tons) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1934/35-1938/39 (av.) | 536.0 | 1,47,990 |
| 1939/40-1943/44 (av.) | 341.3 | 1,50,883 |
| 1944-45 | 33.5 | 56,753 |
| 1945-46 | 39.9 | 16,393 |
| 1946-47 | 158.6 | 1,75,913 |
| 1947-48 | 15.4 | 19,733 |
| 1948-49 | 3.4 | 4,742 |
| 1949-50 | 11.9 | 21,505 |
| 1950-51 | 4,646.5 | 3,60,437 |
| 1951-52 | 741.7 | 9,73,159 |
| 1952-53 | 260.7 | 3,11,443 |

TABLE 37—CONSUMPTION OF TURPENTINE IN PAINT MANUFACTURE*

| | Qty (cwt.) | Val. (lakh Rs.) |
|------|---------------|--------------------|
| 1946 | 6,927 | 3.31 |
| 1947 | 16,272 | 3.99 |
| 1948 | 14,323 | 5.27 |

Census of Manufactures, 1946, I, 196, 198; 1948, I, 256, 258

Rs. 2/12/- per gallon and during 1950-51 between Rs. 2/8/- and Rs. 3/8/- per gallon according to quality. The ex factory price of refined turpentine at Miransahib in June-July 1952 varied from Rs. 2/- to Rs. 2/8/- and that of the Clutterbuck-ganj factory between Rs. 2/12/- and Rs. 3/8/- depending on quality.

Trade—Table 35 gives the imports of turpentine and turpentine substitutes into India. Of the total imports of genuine turpentine in the quinquennium ending March 1939, U.K. supplied 21% and U.S.A., 45%. Other suppliers of turpentine were Sweden and Germany.

Table 36 gives the exports of turpentine from India.

Table 37 gives the consumption of turpentine in paint manufacture in India.

ROSIN

The solid residue remaining in the still after separating turpentine from the oleoresin is known to the trade as rosin or colophony. The rosin is tapped off from the still after melting it by passing high pressure steam through the jacket. The molten mass is strained through filtering cloth and filled into wooden casks of 4 cwt. capacity, the casks being made leak-proof by lining the inside with rosin of the same grade. The rosin contracts on cooling and a further quantity of rosin is admitted later to fill the space. After cooling (1-2 days) the casks are ready for the market. The yield of rosin is c. 0.75 maund per maund of oleoresin distilled.

Rosins varying in colour from pale amber to black are produced in different factories. The U.S.A. system of grading is adopted in this country. Fresh oleoresin from the forests collected in clean containers yields the palest rosin. Rosin produced from aged oleoresin is dark in colour. The grades manufactured in India are A, WW (water white), WG (water glass), N, M, K, I, H, G, F, D, and B. Grade A is extra pale in colour, while grades WW and WG are of pale colour. Grades N, M, K, I, and II are medium pale; grades G and F are red; and grades D and B are black. The grading is done by comparing the colour of a cube of the product with standard rosin cubes in a spectroscope.

Rosin or colophony is a brittle solid with a glassy fracture. It is soluble in ether, chloroform, light petroleum, acetone, alcohol, and most volatile and fixed oils. It softens at c. 75° and melts at 120-135°. It is not usually adulterated as it is probably the cheapest commercial resin available in the market. Rosin consists of a mixture of acids partly in the form of anhydrides, the principal acid being abietic acid (Thorpe, III, 295).

TABLE 38—ANALYTICAL CONSTANTS OF ROSINS*

| | Indian | | American | Imported | |
|-------------------|---------|---------|----------|---------------|---------|
| | Black | WW | | Other foreign | FF Wood |
| m.p. | 98-101° | 106-108 | 110-112° | Up to 130° | 80° |
| Sap. val. | 180 | 186 | 178 | 165-200 | 171.0 |
| Acid val. | 129.5 | 134.1 | 123.6 | 140-185 | 152 |
| Ester val. | 50.6 | 51.9 | 54.4 | 8-35 | |
| Iod. val. (Hanus) | 141.7 | 141.5 | 185.6 | 100-200 | |

* Godbole & Srivastava, *Sci. & Cult.*, 1935-36, 2, 275

Table 38 gives the analytical constants of Indian (from Clutterbuckganj) and imported rosins. Indian standard specifications for rosin for paints and varnishes are as follows: acid val., 155-175; volatile matter, $\geq 2.0\%$; ash content, $\geq 0.5\%$; matter insoluble in toluene, $\geq 1.0\%$; wholly soluble in alcohol, acetone, chloroform, ether, and warm turpentine (I.S. Specification No. 355, 1952).

Rosin is used as a base in the preparation of cheaper grades of varnishes and resinate driers, in the manufacture of soaps, in the production of sizes for paper, and as an ingredient of sealing wax. Grades WW and WG are used in making light varnishes. WW to K grades are used in soap making and grades E, F, and G (especially F) in paper sizes. Rosin is also used in the manufacture of printing inks.

Rosin is employed as an ingredient of casein glues, as binder in dry battery compositions, roofing cements and insulating compositions, in soldering pastes and fluxes, in the manufacture of fire works, match compositions, sharpened shell explosives, and in certain lubricating compositions. It is an ingredient of hair fixing and nail polishing preparations. Rosin is the starting material for the manufacture of rosin oil, rosin spirit, rosin pitch, and abietic acid. It is used in the manufacture of dark varnishes, insecticides, disinfectants, linoleum cements, and plastic compositions. It is applied to belting to reduce slipping and also to bows of musical instruments for ensuring proper contact between the bow and the string. Rosin is an ingredient of core oils and it finds application as flux in general soldering and tin-plating. Rosin oil is used in brewing and flotation.

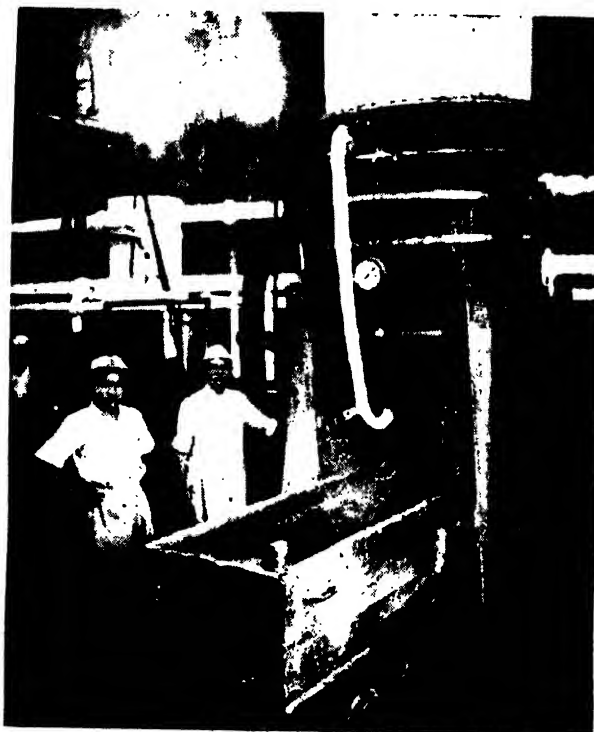
Table 39 gives the production of rosin in India.

The ex factory price of rosin at the Clutterbuckganj factory during October 1952 varied from Rs. 30 to Rs. 38 per maund depending on the grade of rosin; the price of rosin produced in the Miransahib factory varied between Rs. 23 and Rs. 34.

TABLE 39—PRODUCTION OF ROSIN*

| | Qty (tons) |
|-----------------|------------|
| 1944-1946 (av.) | 12,500 |
| 1947 | 6,000 |
| 1948 | 11,328 |
| 1949 | 9,599 |
| 1950 | 8,672 |
| 1951 | 11,690 |
| 1952 | 10,885 |

* Information from the Development Wing, Ministry of Commerce & Industry, Govt. India



Indian Turpentine & Rosin Co. Ltd., Bareilly

FIG. 91—TAPPING OF ROSIN FROM DISTILLATION STILLS

TABLE 40—IMPORTS OF ROSIN

| | Qty (tons) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1934/35-1938/39 (av.) | 2,868.0 | 4,50,756 |
| 1939/40-1943/44 (av.) | 656.8 | 1,36,929 |
| 1944-45 | * | 175 |
| 1945-46 | 205.7 | 92,765 |
| 1946-47 | 662.3 | 8,04,240 |
| 1947-48 | 152.7 | 1,27,318 |
| 1948-49 | 3,207.7 | 21,04,182 |
| 1949-50 | 808.6 | 5,23,600 |
| 1950-51 | 221.9 | 2,11,880 |
| 1951-52 | 266.9 | 2,92,478 |
| 1952-53 | 113.7 | 1,14,171 |

* Negligible

TABLE 41—EXPORTS OF ROSIN

| | Qty (tons) | Val. (Rs.) |
|-----------------------|---------------|---------------|
| 1934/35-1938/39 (av.) | 553.1 | 1,03,746 |
| 1939/40-1943/44 (av.) | 996.5 | 2,69,168 |
| 1944-45 | .. | .. |
| 1945-46 | .. | .. |
| 1946-47 | 39.7 | 27,093 |
| 1947-48 | 57.0 | 51,840 |
| 1948-49 | 156.6 | 2,17,936 |
| 1949-50 | 6.2 | 4,904 |
| 1950-51 | 262.2 | 2,28,469 |
| 1951-52 | 939.1 | 9,83,140 |
| 1952-53 | 196.3 | 2,33,237 |

TABLE 42—CONSUMPTION OF ROSIN

| | 1946 | | 1947 | | 1948 | |
|--------|---------------|--------------------|---------------|--------------------|---------------|--------------------|
| | Qty (tons) | Val. (lakh Rs.) | Qty (tons) | Val. (lakh Rs.) | Qty (tons) | Val. (lakh Rs.) |
| Paper | 1,802 | 12.45 | 1,409 | 9.71 | 1,441 | 11.92 |
| Soap | 2,047 | 14.10 | 1,390 | 10.42 | 1,113 | 11.27 |
| Paints | 1,311 | 9.84 | 1,208 | 10.45 | 1,498 | 15.45 |

Table 40 gives the imports of rosin into India. U.S.A is the principal supplier. The share of U.S.A. in the imports during the decennium 1934-1944 was 94%.

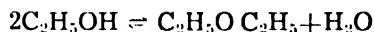
Table 41 gives the exports of rosin from India. Australia and U.K. were the principal importers of Indian rosin during the quinquennium ending March 1939. Exports to Australia have shrunk since 1941-42.

Table 42 gives the consumption of rosin in Indian industries. Of the available supplies of rosin in 1948-49, 53% was used in soap manufacture, 22% in paint manufacture, and 18% as paper size [*Census of Manufactures*, 1946, 1947, 1948; *Eastern Economist*, 1950, 15(14), 519].

ETHER

Ether ($C_2H_5)_2O$ is a highly volatile, inflammable, colourless liquid with a characteristic odour and sweet burning taste. It is used principally as a solvent in industry and as an anaesthetic in surgery.

Ether is generally manufactured by distilling a mixture of alcohol and sulphuric acid and rectifying the distillate. The reaction may be represented by the following equation:



Salts of weak bases and strong acids, such as hydrated ferric sulphate, hydrated chromic chloride, chromic sulphate, aluminium sulphate, crystallized copper sulphate, and cupric chloride

may be employed as catalysts. Ether is formed when alcohol is passed over alum catalyst at a temperature of 200-230°. The process has been worked out on a pilot plant scale at the Indian Institute of Science, Bangalore and a yield of 75% is reported (Jatkar & Watson, *J. Indian Inst. Sci.* 1926, 9A, 71).

Manufacture—Concentrated sulphuric acid and 95% ethyl alcohol are charged into a lead-lined reaction still. The mixture is heated to 125-140° by an internal steam coil. After the commencement of the reaction the supply of alcohol and steam is continued at such a rate that the temperature of the mixture is maintained at c. 127°; further rise in temperature favours the formation of by-products and diminishes the yield of ether. The vapours issuing from the still are scrubbed through caustic soda to eliminate entrained sulphuric acid and fractionated through a column to separate ether from water and alcohol. Ether of technical grade so obtained contains small amounts of alcohol, water, aldehydes, peroxides and other impurities; it is used in industry as a solvent.

Rectified ether on redistillation gives a product which still contains peroxides and aldehydes.

Peroxides may be removed by treatment with potassium permanganate, refluxing with lead peroxide, passing through a column of activated alumina, or shaking with copper-zinc couple in the form of treated zinc dust (*Chem. Abstr.*, 1940,

34, 8111; Dasler & Baner, *Industr. Engng Chem., Anal. Ed.*, 1946, 18, 52; *Chem. Abstr.*, 1948, 42, 7313).

Purified ether is stabilized by the addition of α -naphthol, propyl gallate, or hydroquinone and packed in special containers. Ether should be stored in cool and dark places in opaque containers, preferably in metallic or coloured glass bottles, closed with well fitting glass stoppers or corks covered with tin foil.

Properties and uses—The physical constants of ether are as follows: sp.gr.^{20°}, 0.7135; b.p., 34.5°; m.p., -113° to -117.6°; flash pt., -20°; t., 193.5–193.8°; and p., 36 atm.

Ether is sparingly soluble in water (1 litre of water at 20° dissolves 80 cc. of ether), more soluble in concentrated acids, such as hydrochloric, hydrobromic, and sulphuric acids. It is miscible with most organic solvents. It forms a binary mixture with water (1.3%), b.p., 34.15° and a hydrate, $(C_2H_5)_2O \cdot 2H_2O$, below -3.5°.

Ether vapour forms explosive mixtures with air when present in 1–16% by volume; the relatively low diffusion velocity of ether vapour enhances the risk of explosion. It decomposes in the presence of light and air yielding peroxides, unsaturated compounds, and acids. The peroxides are explosive; it is preferable to distil ether by direct or indirect heating with steam; a naked flame should on no account be used.

Ether is a solvent for fats, waxes, oils, alkaloids, resins, etc. It is used in mixture with various proportions of alcohol in the manufacture of smokeless powders and in the gelatinization of nitrocellulose. As a degreasing agent it finds application in the dry cleaning of textile fabrics, in the cleaning and degreasing of machinery parts, and in the cleaning of metallic surfaces preparatory to electroplating and painting (Thorpe, IV, 386; Gregory, I, 267).

Anaesthetic ether, obtained by the rectification of commercial ether, is much less depressant to the medullary centre and respiration and causes less fall in blood pressure than chloroform. Prolonged ether anaesthesia does not produce toxic action on the heart, and although it produces slight transient toxic effect on the liver and the kidney, it does not give rise to severe delayed poisoning and has a wide margin of safety. The main disadvantage of ether as an anaesthetic is its action on the mucous membrane of the respiratory tract, and for this reason it is not recommended for patients suffering from respiratory ailments. However, there appears to be no basis for not administering ether in pulmonary tuberculosis; thoraco-plastic operations are reported to have been carried out under ether anaesthesia without untoward effects (B.P.C., 1949, 48; Beccher & Adams, *J. Amer. med. Ass.*,

1942, 118, 1204; Murphy, *Amer. Rev. Tuberc.*, 1944, 49, 251).

The concentration of ether necessary to produce anaesthesia is 6–7% by volume in the inspired air, although it may occasionally be necessary to exceed this concentration, especially during induction. Anaesthetic ether is administered in an open mask or by semi-closed or closed circuit methods. When ether alone is used a long time is required for the induction of anaesthesia. In order to reduce the stage of excitement, the current practice is to premedicate the patient with a hypnotic and to employ a mixture of ether with other anaesthetics, such as nitrous oxide or chloroform. This has the advantage of minimizing chest complications and post-operation nausea and vomiting.

Compound Ether Spirit is used in gastric flatulence and in the milder forms of gastralgia. Injection of 1–2 cc. daily and rectal or oral administration are recommended in the management of whooping cough. Gall stones (composed of cholesterol, at least in part) following cholecystectomy have been successfully resolved by the injection of ether. Camphora Aetherea has been employed as a restorative in collapses (U.S.D., 444).

Anaesthetic ether (B.P.) should conform to the following specifications: b.p., 34–35°; wt. per cc., 0.7135 g. at 20°; should not contain more than 0.002% (w/v) of stabilizer; should be free from acetone, aldehyde, methyl alcohol, peroxides, sulphurous acid or other free acids; when 50 cc. of ether are evaporated and dried at 100°, not more than 1 mg. of residue should be left; soluble at 15.5° in 8.5 volumes of water and miscible in all proportions with 90% alcohol, chloroform, and fixed and volatile oils (B.P., 41).

Ether of solvent quality (B.P.) should conform to the following specifications: b.p., 34–36°; wt. per cc., 0.714–0.718 g. at 20°; should not contain methyl alcohol, peroxides, sulphurous acid or other free acids; soluble at 15.5° in 8.5 volumes of water and miscible in all proportions with 90% alcohol, chloroform, and fixed and volatile oils (B.P., 42).

The presence of peroxides can be detected by the potassium iodide test, Rieche's benzidine blue reaction, or Stamm's phenolphthalein reaction. A convenient reagent for the detection of peroxides is prepared by fusing 1 g. titanium sulphate with 20 g. potassium hydrogen sulphate, extracting with water, adding 5 cc. sulphuric acid (d. 1.84), diluting to 500 cc., shaking and filtering; 1 cc. of reagent on shaking with 20 cc. ether for 5 sec. and allowing to stand for 10 min. should not give any yellow colour when viewed in daylight against a white background. The following test has been recommended in B.P.: 8 cc. of potassium iodide-starch solution (in the case of anaesthetic ether)

or 8 cc. of potassium iodide solution (in the case of solvent ether) are taken in a stoppered tube (12 cc.; diam., 1.5 cm.). The tube is filled to the brim with the test specimen and stoppered so that no air bubble is enclosed. The tube is shaken vigorously and set aside in the dark for 30 min.; no brown or reddish colour should be produced in the case of anaesthetic ether; the yellow colour, if produced in the case of solvent ether, should not be deeper than that given by 0.5 cc. of N/1000 iodine solution diluted with 8 cc. of potassium iodide solution (B.P., 42-3).

THE INDIAN INDUSTRY

The manufacture of ether was started by Messrs. Bengal Chemical & Pharmaceutical Works Ltd., Calcutta in 1937 and by the Alembic Chemical Works Company Ltd., Baroda in the subsequent year. Messrs. Lister Antiseptics and Dressing Co. Ltd., Calcutta and Lesco Chemical Works Ltd., Kanpur installed plants for the manufacture of ether during World War II.

The plant at the Bengal Chemical and Pharmaceutical Works Ltd. consists of several self-sufficient units, each consisting of a reaction still, a scrubber, a rectifier, an analyser, and a condenser. The still is fitted with a steam coil for heating the reactants at the initial stage and a pipe extending to the bottom for feeding alcohol. The lid of the still is provided with a vapour outlet and provision is made for inserting a thermometer.

The still is charged with c. 8 gallons of a mixture of 1 part by volume of conc. sulphuric acid (98%) and 2 parts by volume of alcohol (94-96% by volume). The flow of alcohol into the vessel is continuous, except at the beginning when it is interrupted to admit steam under pressure and raise the temperature of the mixture to c. 120° for initiating the reaction. The flow of alcohol and steam is so regulated that the temperature remains at c. 127°. Fresh quantities of sulphuric acid are added from time to time to maintain the initial strength. The distilling vapours are led through a caustic soda bubbler and thence to a fractionating column. The column is provided with trays of the cup-and-bell type up to about a third of its height from the bottom. The vapours are met by a descending column of water previously heated by injecting steam at the bottom of the column. The alcohol fraction is tapped at a height of about two-thirds from the bottom, into a condenser through which water at 50° is circulated. The alcohol is returned to the column a little lower down and the excess drained and sent to the supply tank.

From the upper one-third of the fractionating column, maintained at 40°, the ether vapours are led through a condenser kept at 34°. The condenser functions as an analyser returning the

higher boiling fraction to the upper section of the fractionating column. Rectified ether vapour passes into the condenser, thence to the cooler maintained at 12°, and finally to the storage tank. The yield of ether from alcohol varies somewhat depending upon the atmospheric temperature, being c. 95% of the theoretical during the cooler months. One gallon (c. 8 lb.) of alcohol should normally give c. 4.5 lb. of solvent ether and 2.5 lb. of anaesthetic ether. In actual practice, however, the yields are somewhat less. In the Bengal Chemical and Pharmaceutical Works Ltd., the yield of solvent ether per gallon is about 3.0-3.5 lb. The product satisfies British standard specifications for solvent ether.

For preparing ether of anaesthetic quality, the product is treated with caustic soda and potassium permanganate and further rectified. About 25 lb. of caustic soda are required for every 50 lb. of anaesthetic ether. If excessive amounts of aldehydes are present, the ether is scrubbed through sodium bisulphite liquor or freshly precipitated mercuric oxide, the scrubbing being repeated several times to obtain a product satisfying B.P. specifications. Stabilizers are added to prevent auto-oxidation during storage.

Solvent ether is stored in metallic drums of 28-118 lb. capacity. Anaesthetic ether is stored in amber coloured bottles of 1 lb., 8 oz., and 4 oz. capacity.

Production—Table 1 gives the production of ether during 1943-51 by the Bengal Chemical and Pharmaceutical Works Ltd. (B.C.P.W.) and Alembic Chemical Works Co. Ltd. (A.C.W.).

The annual production capacities of the two factories are as follows: B.C.P.W.—solvent ether, 192,000 lb.; A.C.W.—solvent ether, 264,000 lb.; anaesthetic ether, 180,000 lb.

The annual demand for anaesthetic ether is estimated at 90,000 lb.; that for solvent ether is estimated at 250,000 lb. (Indian Tariff Bd, Rep. Chloroform, Potassium Permanganate, and Ether

TABLE 1—PRODUCTION OF ETHER IN INDIA*

| | (Qty in lb.) | |
|------|--------------|---------|
| | B.C.P.W. | A.C.W. |
| 1943 | 40,631 | 90,651 |
| 1944 | 44,921 | 103,392 |
| 1945 | 6,880 | 14,866 |
| 1946 | 21,202 | 13,800 |
| 1947 | 12,592 | 14,500 |
| 1948 | 7,204 | 14,000 |
| 1949 | 16,413 | 37,000 |
| 1950 | 13,513 | 128,500 |
| 1951 | 20,682 | 140,000 |

* Indian Tariff Bd, Rep. Chloroform, Potassium Permanganate, and Ether Sulphuric P.B. & Anaesthetic Industries, 1947, 18; Information from B.C.P.W. and A.C.W.

TABLE 2—C.I.F. AND SELLING PRICES OF ETHER*
(Price in Rs. as. ps.)

| | II | | | |
|---------|---------|-------------|---------|-------------|
| | Solvent | Anaesthetic | Solvent | Anaesthetic |
| C.i.f. | 0 10 | 1 12 6 | 2 1 | 2 3 7 |
| Selling | 1 1 | 2 10 10 | 2 14 | 3 0 0 |

* Indian Tariff Bd, Rep. Chloroform, Potassium Permanganate, and Ether Sulphuric P.B. & Anaesthetic Industries, 1947, 20

Sulphuric P.B. & Anaesthetic Industries, 1947, 17).

Imports—Separate figures for the imports of ether into India are not available. During the pre-war years India imported annually about 123,000 lb. of solvent ether and 33,500 lb. of anaesthetic ether. Imports of ether are subject to customs duty, the standard rate being 36% *ad valorem*; the preferential rate for U.K. is 24% *ad valorem* (Indian Tariff Bd, Rep. Chloroform, Potassium Permanganate, and Ether Sulphuric P.B. & Anaesthetic Industries, 1947, 17).

Prices—Table 2 gives the c.i.f. price and selling price as given by two firms.

The Tariff Board estimated the cost of production of solvent ether, inclusive of packing, at Rs. 1-10-9 per lb. based on a production of 10,000 lb. per annum and of anaesthetic ether at Rs. 2-13-4 per lb. based on a production of 20,000 lb. per annum. The current selling prices of solvent ether and anaesthetic ether are as follows: B.C.P.W., Rs. 3-5-0 and Rs. 4-12-0 per lb.; A.C.W., Rs. 3-0-0 and Rs. 3-12-0 per lb. The differences in the selling prices are due to the difference in the prices of alcohol at Calcutta and Baroda. The high price of ether in India is due to the high price of alcohol (Indian Tariff Bd, Rep. Chloroform, Potassium Permanganate, and Ether Sulphuric P.B. & Anaesthetic Industries, 1947, 22; Information from B.C.P.W. and A.C.W.).

ETHYL ACETATE

Ethyl acetate, $\text{CH}_3\text{COOC}_2\text{H}_5$, is a colourless inflammable liquid with a pleasant fruity odour and burning taste. It is prepared by the direct esterification of ethyl alcohol and acetic acid. It is also obtained by the reaction of acetyl chloride on ethyl alcohol, acetic anhydride on ethyl alcohol, or silver acetate on ethyl chloride. Ethyl acetate is obtained as a by-product in polyvinyl acetal manufacture.

Ethyl acetate is usually prepared by mixing and warming ethyl alcohol, acetic acid, and sulphuric acid, the latter serving as a dehydrating agent. Sodium acetate may be used in place of acetic acid. The mixture is passed through heat exchangers and then through an esterification

column. The product obtained is a ternary mixture (b.p., 70.2°) of the following composition: ethyl acetate, 82.6%; ethyl alcohol, 8.4%; and water, 9%. Water is added to the condensate to remove the alcohol and returned to the system. The ester carrying c. 4% of water is rectified through a column. Two grades of ethyl acetate are manufactured: pure (c. 99% ethyl acetate) and commercial (85-88% ethyl acetate) [Shreve, 908; *Chem. Engng*, 1948, 55 (4), 78].

Several catalytic processes for the preparation of ethyl acetate have been patented. One of them is based on the action of aluminium ethoxide on acetaldehyde in the presence of aluminium chloride, preferably added during the preparation of ethoxide from alumina and ethyl alcohol. The reaction may be accelerated by melting the ethoxide and dissolving it in anhydrous camphor or alum. Ethyl acetate is obtained in Germany by feeding continuously into a reactor at $0-5^\circ$ acetaldehyde (2 mol.), a slurry of aluminium ethoxide (1 mol.), and absolute alcohol. In another process, patented in U.K., aluminium ethoxide dissolved in an organic solvent, such as xylene, is reacted with acetaldehyde at $0-15^\circ$, when ethyl acetate is obtained (yield, 86%). In yet another process, patented in U.S.A., an alcoholic solution of basic lead acetate is heated with ethylene dichloride in an autoclave at a pressure of 200-500 lb./sq.in. The reaction product consists of a mixture of ethyl acetate and glycol in equal amounts; the lead chloride formed is converted to basic lead acetate (Brit. Pat., 4887; BIOS. Final Rep., 843, item, 22; *Rep. Progr. appl. Chem.*, 1947, 32, 50; Brit. Pat., 1288; U.S. Pat., 2398157).

Properties and uses—The properties of pure and commercial grades of ethyl acetate are given in Table 1.

TABLE 1—PROPERTIES OF ETHYL ACETATE*

| | Pure | Commercial |
|-----------------------------------|--|---|
| Sp. gr. ^{20°} | 0.900-0.904 | 0.882-0.886 |
| Distillation range | Below 75° , none Above 80° , none | Below 70° , none Below 72° , $\geq 10\%$ |
| Flash pt | c. 26°F . | c. 26°F . |
| Acidity | Free acid as acetic, $\geq 0.01\%$ | Free acid as acetic, $\geq 0.02\%$ |
| Non-volatile matter | ≥ 0.003 g./100 cc. | ≥ 0.003 g./100 cc. |
| Water solubility (at 25°) | 100 cc. ethyl acetate dissolves 3.5 cc. water | 100 cc. ethyl acetate dissolves 11.2 cc. water |

* Mellan, 349

ETHYL ACETATE

Ethyl acetate is readily miscible with organic solvents, such as alcohols, ketones, esters, and hydrocarbons. It possesses the unique property of dissolving nitro- and acetyl-cellulose ethers yielding solutions of low viscosity.

Ethyl acetate is valued mainly for its solvent properties. It dissolves oils, fats, waxes, gums, and resins. It is a solvent for nitrocellulose and is used in the manufacture of lacquers, thinners, leather and artificial leather dopes, pyroxylin plastics, and photographic films. Owing to its high solvent power for nitrocellulose, ethyl acetate is employed in the manufacture of artificial hair, artificial silk, and leather. It is also used as a starting material for the synthesis of organic compounds; in making dyes, drugs, flavours, perfumes, esters, phosgene, smokeless powders, and rayons; cleaning preparations for textiles; fumigation of wheat; and extraction of acetic acid from aqueous solutions. Ethyl acetate is occasionally used as a carminative and antispasmodic. It is used externally as a resolvent and as an application for rheumatic pains (U.S.D., 446; Mellan, 349).

Ethyl acetate is manufactured by *Alembic Chemical Works Co. Ltd.*, Baroda, *Kumar Chemicals*, Bombay, and *Sterling Chemicals*, Bombay.

A charge of alcohol, acetic acid, and sulphuric acid is taken in a jacketed reaction still which is gradually heated to c. 75° and refluxed at that temperature for 2 hr. The ester formed is separated by distillation, neutralized with soda ash, treated with calcium chloride, and redistilled. A charge containing 135 lb. ethyl alcohol, 135 lb. acetic acid, and 70 lb. conc. sulphuric acid, gives 100 lb. ethyl acetate.

The total annual installed capacity for the production of ethyl acetate is 24,000 gallons. Information on the total production of ethyl acetate is not available. The *Alembic Chemical Works Co. Ltd.* produced 123 lb. of ethyl acetate in 1948, 34 lb. in 1949, and 265 lb. in 1950 (Information from *Alembic Chemical Works Co. Ltd.*, Baroda).

The Panel on Fine Chemicals have fixed the target of total production of ethyl, butyl, and amyl acetates at 1,500 tons to meet the demands of the paints, varnishes and lacquer industries (*Rep. Panel on Fine Chemicals, Drugs and Pharmaceuticals*, Govt. India, 1947, 13).

ETHYL CHLORIDE

Ethyl chloride, C_2H_5Cl , is a colourless, mobile, inflammable liquid. It is prepared on a commercial scale by (1) the action of hydrogen chloride on ethyl alcohol in the presence of a catalyst; (2) the addition of hydrochloric acid to ethylene in the presence of aluminium or bismuth chloride; and (3) chlorination of ethane. Ethyl chloride is obtained as a by-product in the manufacture of chloral.

Ethyl chloride is produced on a commercial scale

by saturating a mixture of 1 part of zinc chloride in 82 parts of alcohol with hydrochloric acid gas in the cold and distilling in a current of hydrochloric acid gas in a reflux apparatus, the ethyl chloride being collected in a cooled receiver. Chlorides of iron, antimony, or bismuth can also be used as catalyst instead of zinc chloride. The formation of ethyl chloride is partly due to the action of hydrogen chloride on alcohol and partly to the union of nascent ethylene with hydrogen chloride.

In the continuous process for the production of ethyl chloride, anhydrous hydrogen chloride is passed countercurrent to warm 95% ethyl alcohol in a jacketed glass-lined reactor containing 67-80% aqueous zinc chloride solution. The temperature in the reactor is maintained at 135-150° and the pressure at c. 30 lb./sq.in. The vapours of ethyl chloride, water, and hydrogen chloride are passed countercurrent to a stream of water at 80° in a scrubber. The scrubbed vapours pass through one or more towers in countercurrent flow to a downward stream of caustic solution removing the remaining hydrogen chloride, free chlorine, or carbon dioxide; the vapours are next washed with sulphuric acid which removes water, alcohol, ether, and entrained caustic solution. The purified ethyl chloride gas is then condensed. The quantities of raw materials consumed for the production of 1 short ton of ethyl chloride are: ethyl alcohol, 1,500 lb.; and hydrogen chloride, 1,200 lb. Rectified spirit or absolute alcohol is used in the process. This process is becoming less attractive at present due to the increased cost of ethyl alcohol (Kirk & Othmer, 3, 757; Faith, Keyes & Clark, 319).

Increasing quantities of ethyl chloride are being produced by the reaction of hydrogen chloride and ethylene in the presence of a catalyst, such as aluminium chloride. A variety of catalysts has been developed for this reaction, such as aluminium chloride, compounds of antimony, vanadium, tantalum, bismuth, zinc, copper, magnesium, and calcium; sulphuric acid; and sulphur dioxide. Ethylene gas and anhydrous hydrogen chloride, in equimolecular proportions, are passed in a reactor containing a catalyst, such as aluminium chloride, at temperatures varying from -5° to +55° and at pressures between 1 and 9 atm. depending on the particular process used. The reaction product contains a mixture of ethyl chloride and ethylene dichloride. The low boiling ethyl chloride is fractionally distilled off. It is purified by passing the vapour through water, dilute caustic soda solution, and concentrated sulphuric acid to eliminate alcohol, hydrogen chloride, and water. It is then rectified to remove other alkyl chlorides.

Ethyl chloride is also produced by controlled chlorination of ethane; the substitution reaction can take place thermally, catalytically, or photo-

chemically. In the thermal chlorination method, the reaction takes place at c. 300° in the absence of light or catalyst. A mixture of ethane and chlorine (8:1) is fed to a brick-lined reaction vessel, kept at 300–550°. The exit gas consisting substantially of hydrogen chloride, ethyl chloride, and excess ethane, is passed in countercurrent flow through a water absorption system which removes hydrogen chloride from the mixture. The overhead gas, consisting of ethyl chloride and excess ethane is subjected to combined pressure and cooling in order to separate the ethyl chloride [U.S. Pat. 1,242,208 (1917)]. In one modification of the process, the ethane is preheated and sent to the reaction zone, where chlorine is injected at a high velocity through jets, and the heat of reaction removed by a molten salt bath surrounding the reactor. Several types of catalysts, such as metals, metallic oxides or chlorides, and organometallic compounds, accelerate the halogenation reaction. The chlorine to ethane feed ratio varies from 1 to 1.5. The reaction may also be initiated photochemically by using a light source which dissociates the chlorine molecules into atoms. These atoms then start the chain reaction. For commercial purposes, a light source with a radiation of 3000–4000 Å is employed. The reaction may be carried out in liquid or gaseous phase and at high or low temperature. Usually the feed stream consists of equal volumes of ethane and chlorine (Kirk & Othmer, 3, 755).

Owing to its extreme volatility, ethyl chloride should be stored at temperatures below 10° in tightly stoppered bottles. The bottles should be stored in the dark remote from any source of fire.

Properties and uses—Ethyl chloride [m.p., –138.30; b.p., 12.27°; decompn. pt, 500°; d_4^{15} (liquid), 0.90280; $d_4^{12.21}$ (gas), 0.00286; n_D^{20} (liquid), 1.3790; t., 187.2°; p., 51.7 atm.; flash pt, < –18°] has a pungent ethereal odour and a burning taste. It is highly inflammable. The limits of composition of explosive mixtures with air are: lower, 3.6%; upper, 11.2%; optimum, 7.5% when ignition is by electric spark; lower, 6.4%; and upper 11.2% when ignition is by flame. Ethyl chloride is slightly soluble in water (1 part in 3,000), completely miscible with alcohol and ether. It dissolves phosphorus, sulphur, fats, and oils and with metallic chlorides, such as antimony pentachloride and ferric chloride, it forms crystalline compounds (Kirk & Othmer, 3, 751; Thorpe, IV, 358).

Ethyl chloride of B.P. grade contains not less

than the equivalent of 99.5% w/w of C_2H_5Cl ; residue on evaporation should not exceed 0.01%. Limit tests have been prescribed for acidity, alkalinity, chlorides, and ethyl alcohol. Ethyl chloride is estimated by saponifying with excess of standard alcoholic potash and estimating the excess of alkali (B.P., 46).

Ethyl chloride is used for light anaesthesia for minor procedures and as a preliminary agent to put a patient to sleep before administering ether. Its use alone is not safe as the anaesthetic and the toxic doses are nearly the same; further, induction and recovery are so rapid that it is difficult, even for an experienced anaesthetist, to maintain smooth anaesthesia. It is generally used for local anaesthesia by spraying directly on the skin; it absorbs sufficient heat during vaporization to cause superficial freezing in the area to which it is applied, thus destroying the functional activity of the peripheral nerve endings. Good results have been reported with ethyl chloride spray in the treatment of sprains. The spray is also advocated in the treatment of trichopytosis (athletes' foot). Ethyl chloride is also used for the sterilization of bacterial cultures and vaccines.

The usefulness of ethyl chloride in chemical reactions is based on its ability to function as an inexpensive ethylating agent. Ethyl chloride is employed mainly in the manufacture of tetraethyl lead (by reaction with lead-sodium alloy under pressure), ethyl cellulose (by treating alkali cellulose with ethyl chloride), plastics, and ethylation of dyes and drugs. In the manufacture of tetraethyl lead and ethyl cellulose, there is no competitive material for ethyl chloride. It is also used as a catalyst in synthetic rubber manufacture. It is one of the most useful reagents in synthetic organic chemistry.

The Indian industry—Ethyl chloride is manufactured by the *Alembic Chemical Works Co. Ltd.*, Baroda. It is obtained as a by-product in the manufacture of chloral hydrate in a semi-continuous countercurrent plant in which dry chlorine gas is made to react with alcohol. The mixture of ethyl chloride and unreacted chlorine is passed through water to remove chlorine and the residual gas is passed through lime towers and condensed by ice-cooled water or mechanical refrigeration.

The product is marketed in 30, 50, and 100 g. tubes with spray devices and also in 3 and 5 cc. glass ampoules. The annual production capacity is 50,000 tubes. Actual production was 9,300 tubes in 1948, 4,812 tubes in 1949, and 18,787 tubes in 1950 (Information from *Alembic Chemical Works Co. Ltd.*, Baroda).

TABLE 1—IMPORTS OF ETHYL CHLORIDE FROM U.K.*

| | Qty (gal.) | Val. (Rs.) |
|------|---------------|---------------|
| 1942 | 122 | 659 |
| 1943 | 10 | 76 |
| 1944 | 106 | 583 |
| 1945 | 316 | 1,906 |
| 1946 | 1,007 | 6,059 |
| 1947 | 429 | 2,626 |
| 1948 | 333 | 2,442 |

* Tr. U.K.

Table 1 gives imports of ethyl chloride into India from U.K. in recent years.

EXPANDED METAL INDUSTRY

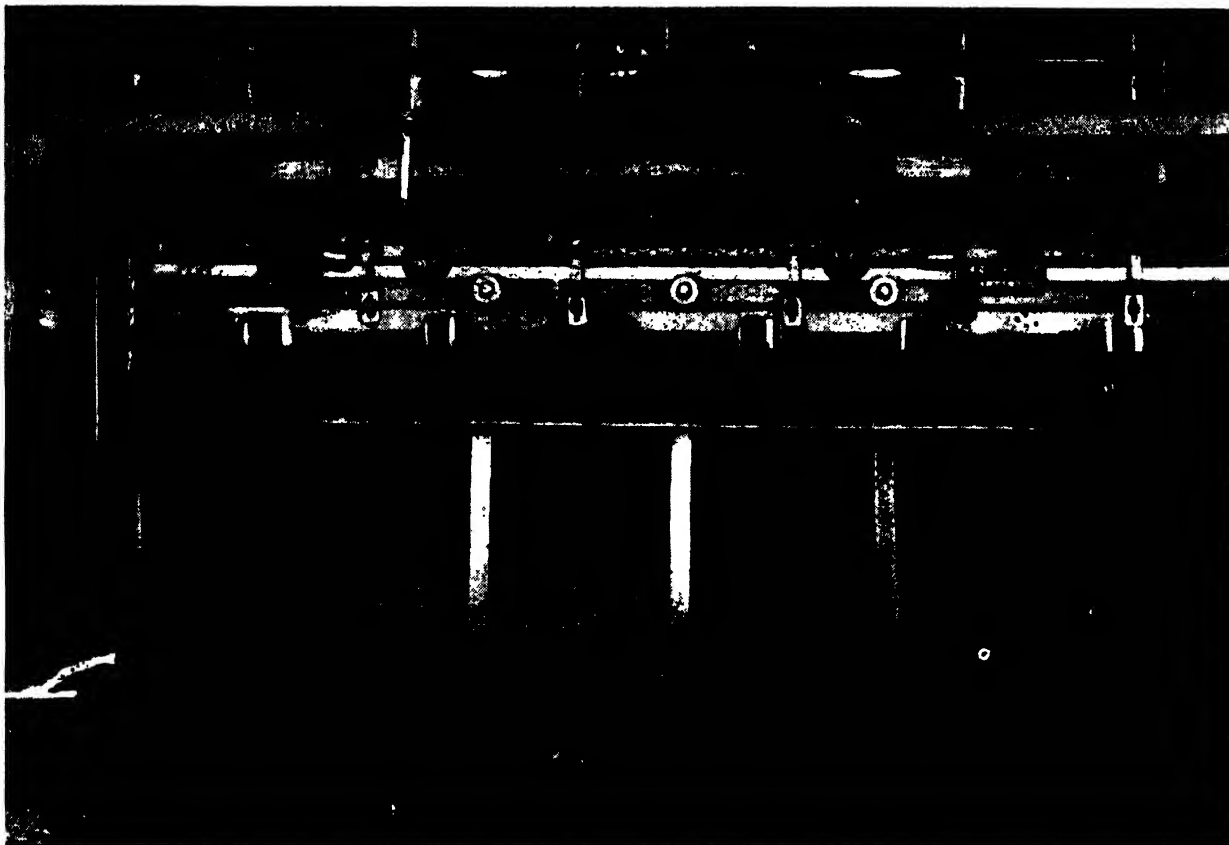
Expanded metal is produced from sheet metal by slitting and stretching the strands formed into a lattice. It has no joints, welds, loose or separate shanks, or attachments. It is used for a variety of engineering purposes, e.g. for reinforcing concrete in roads, foundations, arches, bridges, grain silos, tanks, dams, piers, abutments, pipes, and conduits. It is also used for fencing, doors, windows, ventilators, guards for machinery, partitions, ballast screens, and racks in railways. The more important consumers of expanded metal are the railways, the tramways, and Public Works and Stores Departments.

The first factory in India for the manufacture of expanded metal, *Calcutta Expanded Metal Mfg Co. Ltd.*, Calcutta was started in 1938. This was followed in 1941 by the *India Expanded*



Hindustan Wire and Metal Products Ltd., Calcutta

FIG. 91—SHEARING MACHINE SHOWING FEEDING PLATFORM



Hindustan Wire and Metal Products Ltd., Calcutta

FIG. 92—SHEARING MACHINE SHOWING FINISHED EXPANDED SHEET

Metals Ltd., Bombay. The productive capacities of these factories were fully utilized for meeting the requirements of defence services and Government Departments during World War II. Attempts were made to import machinery from U.S.A. under the lease-lend arrangement with a view to enhance production. The machinery was sold to the *Hindustan Wire and Metal Products Ltd.*, Calcutta and *Kaycee Industries Ltd.*, Lahore. Messrs. *Variety Industrial Engineering Co. Ltd.*, Calcutta was started in 1949. There are altogether four factories in the Indian Union producing expanded metal at present.

Raw materials—The basic raw materials required for the production of expanded metal are mild steel sheets and plates. B.S. specification No. 405 (1945) for sheets and plates required for expanded metal are: ultimate tensile stress for plates $\frac{1}{8}$ in. or more in thickness, 26–32 tons/sq.in., for sheets $\frac{1}{8}$ in. or less in thickness, 20–28 tons/sq.in.; the steel shall not contain more than 0.06% of sulphur or of phosphorus.

Indian factories obtain their supplies of plates and sheets (10–18 gauge) from the *Tata Iron and*

Steel Co. Ltd., Jamshedpur and the *Indian Iron & Steel Co. Ltd.*, Burnpur. Plates and sheets are double annealed and of dead soft quality; they are tested and certified by the Government Metallurgical Department and supplied under permit by the Iron and Steel Controller, Calcutta. The physical properties and chemical composition of the materials are as follows: tensile strength, 70,000 lb./sq.in.; elastic limit, 55,000 lb./sq.in.; C, 0.06–0.08%; Mn, 0.4%; and P, 0.035%.

Manufacture—Expanded metal is made by slitting rolled plate or sheet and stretching the strands at right angles to the plane to form a network of diamond-shaped meshes. An automatic shearing machine in which two sets of knives are simultaneously used for slitting and stretching is employed. Different sets of knives are required for different sizes of meshes.

The machinery installed in Indian factories is mostly imported. Recently heavy presses made in India have been installed in the *Calcutta Expanded Metal Mfg Co.* and *Variety Industrial Engineering Co.* They are reported to have given full satisfaction.

EXPANDED METAL INDUSTRY

Sizes and specifications—Expanded metal produced in India should conform to Indian Railway Standard Specifications based on British and American Standard Specifications. Out of the 48 specified types in popular demand only a few are made in India. The following sizes [B.S. No. 405 (1945)] are not produced in India: XM 1 to XM 10—6 in. S.W.M. \times 15 $\frac{1}{2}$ in. L.W.M.; XM 11 to XM 20—4 $\frac{1}{2}$ in. S.W.M. \times 12 in. L.W.M.; XM 21 to XM 28. XM 30—3 in. S.W.M. \times $\frac{7}{8}$ in. L.W.M.; and XM 140 to XM 150— $\frac{1}{4}$ in. S.W.M. \times 7/16 in. L.W.M. The manufacture of expanded metal lathing is still in the experimental stage (Indian Tariff Bd, Rep. *Indian Expanded Metals Industry*, 1949, 25).

Production—Table 1 gives the quantities of steel

TABLE 1—ALLOTMENT OF PLATES AND SHEETS TO MANUFACTURERS
(Qty in tons)

| | 1947 | 1948 | 1949 | 1950 |
|---|-------------------|-------|------------------|-------------------|
| Calcutta Expanded Metal Mfg. Co. Ltd. | 643 | 471 | 435 | 915 |
| Indian Expanded Metal Ltd. | 181.4 | 180 | 110 | 180* |
| Hindustan Wire & Metal Products Ltd. | 144 $\frac{1}{2}$ | 626.5 | 607 | 800* |
| Variety Industrial Engineering Co. Ltd. | .. | .. | 91 $\frac{1}{2}$ | 270 $\frac{1}{2}$ |

* Relates to three quarters of the year only

$\frac{1}{2}$ Relates to two quarters only

$\frac{1}{4}$ Relates to one quarter only

TABLE 2—ANNUAL REQUIREMENTS OF PLATES AND SHEETS*

| | Qty (tons) |
|---|------------|
| Calcutta Expanded Metal Mfg. Co. Ltd. | 1,500 |
| Hindustan Wire & Metal Products Ltd. | 1,200 |
| Indian Expanded Metals Ltd. | 300 |
| Variety Industrial Engineering Co. Ltd. | 360 |
| Total | 3,360 |

Indian Tariff Bd, Rep. *Indian Expanded Metals Industry*, 1949, 24

sheets allotted to manufacturers during the period 1947-50.

Table 2 gives the estimated annual requirements of plates and sheets by the four factories, on the basis of single shift working.

Table 3 gives the rated capacity and production of Indian factories.

The annual demand for expanding metal has been estimated at 3,000 tons and the annual production at 1,800 tons.

Imports—Data relating to imports of expanded metal are not available. In the pre-war years about 2,000 tons of expanded metal valued at Rs. 5 $\frac{1}{2}$ lakhs were being annually imported into India. Supplies came mainly from U.K., Germany, Belgium, and Japan. Imports during recent years have been negligible. India imported 13.04 tons of expanded metal (val., Rs. 12,803) from U.K. in 1946-47 and 31.5 tons (val., Rs. 37,395) in 1947-48. Imports of iron or steel expanded metal are subject to a revenue duty of 19.17/32 $\frac{1}{2}$ ad valorem. Imports from Burma are free of duty.

The possibility of an export market for Indian expanded metal has been referred to in the report of the Indian Tariff Board. There was a demand for this product from Burma in January-May 1949.

Prices—Table 4 gives the fair selling prices of indigenous expanded metal products in 1948-49.

TABLE 4—FAIR SELLING PRICES OF EXPANDED METAL*

| size, short-Mesh way in. | Strand thickness in. | Gauge of sheet | Finished size S.W.M. \times L.W.M. ft. | | Av. price/sq. ft. As. Ps. |
|--------------------------|----------------------|----------------|--|-----------------|---------------------------|
| do. | 3/32 | 18 | 12 | 4 $\frac{1}{2}$ | 3 4 |
| do. | do. | 18 | 12 | 8 $\frac{1}{2}$ | 4 4 |
| do. | 1/8 | 16 | 12 | 4 $\frac{1}{2}$ | 3 4 |
| do. | do. | 16 | 12 | 8 $\frac{1}{2}$ | 2 10 |
| do. | 1 | 16 | 12 | 4 | 4 2 |
| do. | 1 $\frac{1}{2}$ | 16 | 12 | 4 $\frac{1}{2}$ | |
| do. | do. | 16 | 12 | 8 $\frac{1}{2}$ | |
| do. | do. | 16 | 12 | 6 | |

Indian Tariff Bd, Rep. *Indian Expanded Metals Industry*, 1949, 11

TABLE 3—PRODUCTION OF EXPANDED METAL IN INDIA*
(Qty in tons)

| | Rated capacity | Actual production | | | | | |
|---|----------------|-------------------|---------|-------------------|-------------------|-------------------|-------------------|
| | | 1945-46 | 1946-47 | 1947-48 | 1948 | 1949 | 1950 |
| Calcutta Expanded Metal Mfg. Co. Ltd. | 1,500 | .. | 875 | 1,125 | 720 | .. | .. |
| Hindustan Wire & Metal Products Ltd. | 1,200 | .. | 500 | 325 | 640 | 518 | 908 |
| Indian Expanded Metals Ltd. | 180-250 | 49 | 145 | 104 | 99 | 162 | 146 |
| Variety Industrial Engineering Co. Ltd. | 360 | .. | .. | 240 $\frac{1}{2}$ | 240 $\frac{1}{2}$ | 240 $\frac{1}{2}$ | 240 $\frac{1}{2}$ |

* Indian Tariff Bd, Rep. *Indian Expanded Metals Industry*, 1949, 26

$\frac{1}{2}$ Based on an average of 20 tons per month

TABLE 5—PRICES OF EXPANDED METAL

| Size of mesh (in. × in.) | Section of strand (in. × in.) | Size of sheets (ft. × ft.) | Price/ sq. ft. As. Ps. |
|-----------------------------------|----------------------------------|-------------------------------|------------------------------|
| 3 × 7 $\frac{1}{2}$ | 1/4 × 1/8 | 8 × 12 | 5 0 |
| do. | 3/16 × 1/8 | do. | 4 6 |
| do. | 1/8 × 1/8 | do. | 3 3 |
| 1 $\frac{1}{2}$ × 4 $\frac{1}{2}$ | 1/4 × 1/8 | do. | 10 0 |
| do. | 3/16 × 1/8 | do. | 8 0 |
| do. | 1/8 × 1/8 | do. | 5 9 |
| do. | 1/8 × 16G | do. | 4 0 |
| 1 × 8 | 1/8 × 1/8 | do. | 7 0 |
| do. | 1/8 × 16G | do. | 5 0 |
| do. | 1/8 × 18G | do. | 4 3 |
| 3/4 × 2.29/64 | 1/8 × 1/8 | do. | 9 6 |
| do. | 1/8 × 16G | do. | 5 9 |
| do. | 1/8 × 18G | do. | 4 9 |
| do. | 2/32 × 18G | do. | 4 0 |
| 1/2 × 2 | 1/8 × 16G | 8 × 9 | 8 0 |
| do. | 3/32 × 18G | do. | 5 9 |
| 3/8 × 1.11/16 | 1/16 × 18G | 8 × 6 | 6 9 |
| do. | 1/6 × 18G | do. | 6 1 |
| do. | 1/8 × 16G | do. | 10 3 |
| do. | 1/8 × 20G | do. | 6 9 |
| do. | 3/32 × 18G | do. | 7 9 |
| do. | 3/32 × 20G | do. | 6 9 |
| 1/4 × 1 $\frac{1}{4}$ | 1/8 × 16G | do. | 13 6 |
| do. | 3/32 × 18G | do. | 11 6 |
| do. | 3/32 × 20G | do. | 10 6 |
| 3/16 × 27/32 | 3/32 × 20G | 8 × 4 | 13 6 |

The c.i.f. price of imported expanded metal (1 $\frac{1}{2}$ × $\frac{1}{4}$ in. × $\frac{1}{4}$ in.) in 1949 was Re. -/5/3 per sq. ft.

Table 5 gives the prices fixed by the Metal Panel of the Engineering Association of India. The prices are nett f.o.r. Calcutta and are subject to alteration with notice.

Expanded metal from non-ferrous metals, e.g. brass and copper, was being produced in Indian factories during the war years. Production has now ceased owing to lack of demand. Attempts are being made to produce expanded metal from aluminium sheets.

EXPLOSIVES

Explosives are solid, liquid, or gaseous substances which, when submitted to a local initiatory impulse, such as shock, friction, and spark suffer rapid decomposition with the production of considerable quantities of heat and large volumes of gases which may occupy many times the volume of the original substance. Explosive processes are characterized by the sudden release of heat and gases which exert intense pressure on the surroundings. The more heat and gases an explosive produces per unit volume, the more powerful it is (Thorpe, IV, 454; Encyclopaedia Britannica, 8, 987).

Explosives may be considered under two broad classes—propellant explosives and detonating high explosives. Propellants undergo autocombustion at rates varying from a few inches per minute to c. 400 m. per sec., whereas detonating high explosives undergo almost instantaneous detonation or decomposition, the rate of detonation varying from 1,000 to 8,500 m. per sec. The latter may be further subdivided into primary or initiatory explosives and high explosives. Primary explosives are sensitive to heat, impact, or friction and detonate instantly when subjected to such physical forces. High explosives, which may be burned without explosion due to their insensitiveness, need a violent shock, e.g. a mechanical blow or the explosion of an adjacent charge, in order to detonate them. High explosives may again be considered for convenience under military high explosives and commercial blasting explosives. The former consists of pure or mixed organic nitrated compounds while blasting explosives which are less violent are mixtures of explosive and non-explosive ingredients (Encyclopaedia Britannica, 8, 987).

The composition, sensitiveness, and the effects of different explosives vary considerably. Common tests for explosives include thermal stability, sensitivity to mechanical impact, ease of ignition, power (measured by the so-called Trauzl lead-block expansion or by the ballistic mortar), heat of expansion, and volume of gas formed. Table 1 gives the heats of explosion and volumes of gas produced by some explosives.

TABLE 1—EXPLOSIVE CHARACTERISTICS OF HIGH EXPLOSIVES^a

| | Heat liberated cal./g. | Gas liberated cc./g. |
|--|---------------------------|-------------------------|
| Ammonium nitrate | 346 | 980 |
| Glycol dinitrate | 1,655 | 737 |
| Nitroglycerin | 1,478 | 713 |
| Pentaerythritoltetranitrate (PETN) | 1,385 | 790 |
| Mannitol hexanitrate | 1,454 | 694 |
| Nitrocellulose (13.3% N) | 951 | 871 |
| Cyclotrimethylenetrinitramine (Cyclonite) | 1,300 | 908 |
| Dinitrobenzene | 820 | 727 |
| Trinitrobenzene | 1,065 | 670 |
| Trinitrotoluene (T.N.T.) | 925 | 730 |
| Picric acid | 1,000 | 675 |
| Ammonium picrate | 800 | .. |
| Trinitrophenylmethyl nitramine (Tetryl) | 1,120 | 760 |
| Hexanitrodiphenylamine (Hexvl) | 1,035 | 675 |

Kirk & Othmer, 6, 55

^a Reduced to 0° and 760 mm. pressure

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HIGH EXPLOSIVES

For commercial or military use, high explosives should be safe to transport and handle and they should be stable during storage. Military explosives used as bursting and demolition charges consist of pure or mixed substituted organic compounds such as trinitrotoluene (T.N.T.), cyclotrimethylenetrinitramine (Cyclonite), trinitrophenylmethylnitramine (Tetryl), trinitrophenol (Picric acid), ammonium picrate, and pentaery-

thritoltetranitrate (PETN). The more important single compound high explosives are listed in Table 2. With the exception of the important high explosive, ammonium nitrate, the others are organic compounds (Kirk & Othmer, 6, 20-54).

The single compound high explosives are also used for the formulation of binary explosives, plastic explosives, and blasting explosives. Binary explosives are prepared by mixing T.N.T. and another explosive with or without a non-explosive

TABLE 2—SINGLE COMPOUND HIGH EXPLOSIVES

| | Uses | Properties |
|--|--|---|
| Ammonium nitrate | Ingredient of blasting explosives, propellants, and shell & bomb bursting charges | White crystalline solid made from ammonia and nitric acid |
| Nitroguanidine | Limited use in propellants & trench mortar shells | White crystalline solid prepared by the dehydration of guanidine nitrate with sulphuric acid |
| Glycoldinitrate | Used to a limited extent in the manufacture of low-freezing dynamites | Colourless liquid at ordinary temperatures |
| Diethylene-glycoldinitrate | Used in Germany as a substitute for nitroglycerin in charges designed for rocket-propulsion devices | Colourless liquid prepared by the nitration of glycol with mixed acid |
| Nitroglycerin | Sensitive to shock and friction and seldom used alone as explosive; used largely in the manufacture of dynamites and propellants in admixture with other materials | Colourless oily liquid formed by the nitration of glycerine with mixed acid |
| Diglycerin-tetranitrate | Used with nitroglycerin in the manufacture of low-freezing dynamite | Viscous liquid formed by the nitration of glycerine and diglycerine |
| PETN | Used in detonating fuze and primary composition in composite explosives as booster | Colourless crystals made by the nitration of pentaerythritol with strong (94%) nitric acid |
| Mannitol hexanitrate, nitromannitol or hexanitromannitol | Used for loading commercial blasting caps | Colourless crystals prepared by the action of nitric and sulphuric acids on mannitol |
| Nitrocellulose | Used in propelling powders and to a small extent in the manufacture of gelatin dynamites | Fibrous white solid prepared by nitration of cellulose; it is made in 2 forms: guncotton (relatively insoluble in ether and alcohol) containing 13% and more of nitrogen & collodion cotton (sol. in ether and alcohol) containing less than 12.3% nitrogen |
| Nitrostarch | Used in blasting and demolition explosives | Granular friable solid |
| Cyclonite | Extensively used as base charge for detonators & as ingredient of explosives for shells & bombs | Colourless crystals made by the destructive nitration of hexamethylene tetramine with conc. nitric acid |
| <i>m</i> -Dinitrobenzene | Used to a limited extent as substitute for T.N.T. & other high explosives, generally in mixture with ammonium nitrate or other high explosive | Almost colourless crystals made by treating nitrobenzene with sulphuric and nitric acids |
| 1, 3, 5-Trinitrobenzene | Limited application | Yellowish crystals prepared by the nitration of <i>m</i> -dinitrobenzene or by the oxidation of T.N.T. by sulphuric acid & sodium dichromate |
| 2, 4, 6-Trinitrotoluene (T.N.T.) | Widely used as a bursting charge for shells, bombs, & grenades, as an ingredient of binary explosives and propellant compositions | Yellowish crystalline powder (m.p., 80.5-80.6°) made by nitration of toluene with mixed acids |
| Picric acid | Used in detonating fuze, as ingredient of pyrotechnic compositions, and as bursting charge explosive | Yellow crystals prepared by the nitration of mixed phenol sulphonates |

Table 2 contd.

| | Uses | Properties |
|------------------|--|---|
| Ammonium picrate | Used as military explosive for loading armour-piercing shells | Red crystals made by the neutralization of a hot aqueous solution of picric acid with ammonia water |
| Tetryl | Used as a base charge in blasting caps, as booster explosive in shells, as bursting charge in aircraft cannon shell and in binary explosives | Light yellow or buff crystals prepared by the action of mixed sulphuric and nitric acids on dimethylaniline in a multiple stage nitration |
| Hexyl | Used in Germany as a substitute for T.N.T. | Yellow crystals prepared by the nitration of diphenylamine, N-methyldiphenylamine, or picryl- <i>p</i> -nitraniline |

TABLE 3—BINARY HIGH EXPLOSIVES

| | |
|-----------|---|
| Amatols | 80-20 and 50-50 ammonium nitrate-T.N.T. mixtures known as 80-20 Amatol and 50-50 Amatol; for loading with 80:20 mixture the hot materials are mixed and extruded; 50-50 Amatol is loaded by pouring |
| Tritonal | Cast 80-20 T.N.T.-flake aluminium mixture; extensively used in bombs due to its blast effect |
| Tetrytol | 70-30 tetryl-T.N.T. mixture; used as a demolition explosive and bursting charge for mines |
| Pentolite | Mixture of PETN and T.N.T.; 50:50 mixture used as bursting charge for grenades and as booster-surround charge |
| Picratol | Ammonium picrate and T.N.T. in 50:50 mixture used for armour-piercing projectiles |
| Cyclotol | Cyclonite-T.N.T. mixture (60:40) used during World War II as bursting charge for bombs |

material. Table 3 lists some binary high explosives suitable for melt loading of ammunitions for military purposes (Kirk & Othmer, 6, 56-58).

Plastic explosives are mixtures of one or more explosive compounds with materials, such as wax capable of forming plastic masses, which can be press-loaded or formed by hand. PETN and cyclonite are in demand for this type of explosives.

BLASTING EXPLOSIVES

Important among the blasting explosives are gunpowder, dynamite, ammonals, permissible explosives, and Sprengel explosives.

Gunpowder—Gunpowder, also called black powder, consists of a mixture of potassium nitrate, sulphur, and charcoal roughly in the proportions of 75, 10, and 15 respectively. It is made generally in granular and pellet forms. Once extensively used as a military propellant, gunpowder has lost its supremacy when smokeless powders were introduced towards the close of the nineteenth century. Gunpowder is now used mainly for blasting and sporting purposes.

Dynamites—Blasting explosives based on nitroglycerin have attained great importance in industrial blasting work. Guhr dynamite, the first practical dynamite patented by Nobel, consists of a porous non-explosive absorbent, e.g. kieselguhr, charcoal, mixed with nitroglycerin in such proportions that the resulting mixture is dry and granular in structure.

Straight dynamites consist of nitroglycerin absorbed on suitable materials which though not explosive separately are capable of sustaining the explosion. The materials used for absorbing the active base include sodium nitrate, wood meal, charcoal, etc.; a small amount of calcium carbonate is added as an antacid. The rate of detonation increases with the increase in the amount of nitroglycerin. In recent formulations, nitroglycerin has been replaced by nitrated mixtures of glycerine and polyhydric alcohols including sugars. The standard '40' dynamite used by the U.S. Bureau of Mines in its comparative tests contains: nitroglycerin, 40; sodium nitrate, 44; wood pulp, 15; and calcium carbonate, 1%. Straight dynamites were formerly used extensively in mining and quarrying, but on account of cost they have been replaced to a considerable extent by ammonia dynamites.

Blasting Gelatin or Gelatin Dynamite is a stiff jelly formed by colloiding nitrocellulose (7-8%) with nitroglycerin; it contains also a small amount of an antacid, such as calcium carbonate, magnesium carbonate, or zinc oxide. Blasting gelatin is the most powerful and brisant of industrial explosives.

Gelatin dynamites are formed by substituting blasting gelatin for nitroglycerin in dynamites. For these preparations a lesser proportion of nitrocellulose is employed to make a softer jelly than that used in blasting gelatin. The main advantage of gelatin dynamites over straight dynamites is a much smaller tendency to exude the liquid nitric esters which increases safety in their use. They are strong explosives with good

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gas volume and brisance value. They are used in submarine operations and seismic prospecting work. Gelignite, a form of gelatin dynamite much used in U.K., has the following composition: nitroglycerin, 61.1; nitrocellulose, 3.8; potassium nitrate, 27.6; wood meal, 7.2; and chalk, 0.3%.

Ammonia dynamites contain nitroglycerin or other sensitizing agent together with ammonium nitrate, as part or whole replacement of sodium nitrate, and a combustible material like wood flour. The gases produced during explosion increase in proportion to the ammonium nitrate content. Rex Powder, produced in U.K., contains: nitroglycerin, 12; ammonium nitrate, 59.5; combustible material, 7.7; and sodium chloride, 19.5%. Ammonia dynamites have good brisance, sustained pressure, and pushing action.

Ammonia Gelatin Dynamites are similar to ammonia dynamites and are obtained by replacing nitroglycerin in ammonium dynamites by nitrocellulose. They are superior to gelatin dynamites as regards gas volume and pushing effect although slightly inferior to ammonia dynamites. They are mainly used for mining and quarrying.

Ammonals—Ammonals are industrial explosives containing ammonium nitrate, aluminium powder, and a combustible material like charcoal. The oxidation of aluminium releases large quantities of heat. A typical composition contains: ammonium nitrate, 94; aluminium powder, 3; and charcoal, 3%.

Chlorate and perchlorate explosives are highly sensitive to impacts and friction. Dynobel, an explosive typical of this class, contains: potassium chlorate, 27; wood meal, 9.5; nitroglycerin, 32.5; and ammonium oxalate, 29.5%.

Permissible explosives—Special explosives are required for use in coal mines where the risk of igniting fire damp (methane mixed with air) and coal dust are ever present. The use of blasting powders, explosives rich in nitroglycerin, aluminium powder, etc. are particularly hazardous. Permissible explosives contain large proportions of ammonium nitrate and mineral salts, such as ammonium oxalate and sodium chloride. Rex Powder and Dynobel are typical of permissible explosives. Liquid carbon dioxide has been employed in U.S.A. for blasting purposes in coal mines. The liquid is placed in a steel shell provided with a shear disc along with a cartridge containing sodium chlorate, aluminium powder, and charcoal with means for firing it electrically. When the cartridge is fired, the carbon dioxide vaporizes, shears the disc, and the gases burst out (*Encyclopaedia Britannica*, 8, 990).

Sprengel explosives—A class of explosives, suggested by Sprengel in 1871, consists of mixtures

of an oxidizing agent and a combustible material mixed immediately before use. Liquid oxygen explosives (L.O.X.) form a special case of Sprengel explosives. They are mechanical mixtures of a combustible absorbent material (usually carbon black, lamp black, or wood pulp) and liquid oxygen; metallic powders, such as aluminium and ferrosilicon, may also be added. As the proportion of metallic powder is increased, the rate of combustion is accelerated and the brisance or shattering effect is increased.

The main field of application of L.O.X. is in open cast mining and quarrying. The explosive is used in the following way: the dry and inert cartridge is soaked in liquid oxygen to saturation in wide-mouthed soaking vessels, the liquid oxygen being transported to the blasting site in special vacuum containers. The cartridge is placed in the bore hole which must be straight and of ample section to allow the cartridge to pass easily to its bottom. After loading the charge the hole is tamped in the usual way and fired with the help of a detonator or a detonating fuse. A disadvantage of the L.O.X. is that the number of shot holes which can be fired simultaneously is limited to the number of holes which can be prepared within the time from starting to load the shot holes to the completion of the job. But this is more than compensated by the safety and economy permitted by its use (*Indian Inst. Engr.*, 1946, 48, 393).

PRIMARY OR INITIATORY EXPLOSIVES

Initiators are sensitive chemical compounds capable of initiating detonation in a comparatively large quantity of main explosive. They are used in caps for the ignition of propellants and in detonators to effect the detonation of high explosives. The principal compounds under this class of explosives are mercuric fulminate, lead azide, lead styphnate, and diazodinitrophenol (DDNP). Other materials sometimes used as initiators are mercuric fulminate-chlorate mixtures, silver fulminate, silver azide, tetracene (guanylnitroso-aminoguanilyltetracene), cyanuric triazide, lead dinitroresorcinate, and lead dinitrosoresorcinate.

To this class also belong the various priming compositions employed to provide a sudden burst of flame to ignite an initial detonating agent, a propellant, a fuze powder, or a pyrotechnic composition. They are worked by impact, stab action, percussion, friction, or flame, and are used in commercial and military devices, such as blasting caps, fuzes, small-arm cartridges, artillery and rocket igniters, incendiary compositions, and pyrotechnic compositions.

Most priming compositions consist of mixtures of one or more detonating agents with oxidizers,

TABLE 4—TYPICAL PRIMING COMPOSITIONS*
(Figures indicate percentages)

| Mixtures of non-explosive ingredients | | | |
|--|-----|------|------|
| Potassium chlorate | 55 | 60 | 50.5 |
| Lead thiocyanate | 45 | .. | .. |
| Antimony sulphide | .. | 30 | 26.3 |
| Cuprous thiocyanate | .. | 3 | .. |
| Sulphur | .. | 7 | 8.8 |
| Ground glass | .. | .. | 12.4 |
| Shellac | .. | .. | 2.0 |
| Mixtures based on mercuric fulminate | | | |
| Mercuric fulminate | 19 | 32 | 28 |
| Potassium chlorate | 33 | 45 | 14 |
| Antimony sulphide | 43 | 23 | 21 |
| Black powder | 2.5 | .. | .. |
| Sulphur | 2.5 | .. | .. |
| Ground glass | .. | .. | 35 |
| Shellac | .. | .. | 2 |
| Mixtures of non-explosive ingredients and non-initiating or weak initiating explosives | | | |
| Potassium chlorate | 53 | 52.7 | .. |
| Lead thiocyanate | 25 | 24.8 | .. |
| Antimony sulphide | 17 | 11.9 | 5 |
| Barium nitrate | .. | .. | 42 |
| Calcium silicide | .. | .. | 18 |
| T.N.T. | 5 | .. | .. |
| PETN | .. | 9.9 | .. |
| Lead styphnate | .. | .. | 35 |
| Gun | .. | 0.9 | .. |
| Mixtures based on lead azide | | | |
| Potassium chlorate | 53 | 33.4 | .. |
| Lead thiocyanate | 25 | .. | .. |
| Antimony sulphide | 17 | 33.3 | .. |
| Silicon carbide | .. | 5.0 | .. |
| Lead azide | 5 | 28.3 | .. |

* Kirk & Othmer, 6, 8

fuels, sensitizers, and binding agents. A few priming compositions are listed in Table 4.

A friction primer used in pyrotechnic flares consists of a braided wire coated with red phosphorus and shellac and pulled through a pellet consisting of potassium chlorate, 88, charcoal, 10, and dextrin, 2%.

• PROPELLANTS

Propellants are moderated explosives which on initiation burn to produce gases and force out the projectile as in a cannon. Important among propellant explosives are gunpowders or black powders and smokeless powders. The main feature of these explosives is that the rate of energy released by autocombustion is controllable within limits.

The manufacture of gunpowder comprises the following operations, which are carried out in

separate buildings: (1) preliminary pulverizing of ingredients, (2) mixing, (3) pressing, (4) cutting of press cake, (5) granulation or 'corning,' (6) drying and glazing, and (7) packing. Potassium nitrate is purified and converted to fine crystals. Charcoal made by the destructive distillation of light and porous wood, such as dogwood, alder, willow, and hazel wood, is ground in a cone mill to a powder finer than 30-mesh. Sulphur is ground in iron edge-runner mills avoiding the production of static electricity. About 80–100 lb. of ground ingredients are mixed mechanically, sieved, and again ground with small quantities of water in an edge-runner mill to obtain a mill cake of uniform appearance.

The mill cake is broken up with a wooden mallet and irregular broken pieces converted into grains and sieved into different meshes. The rounded grains thus produced are polished in rotating drums. A small quantity of graphite is sometimes added to produce a more impervious glaze. The glazing process renders the powder safe and also increases the 'density' of the powder. The glazed powder is dried in shallow wooden trays at 38–46° and finished by rotating in horizontal canvas reels. The products are graded as Pebble, Prismatic Powders, Brown Cocoa Powder, Sporting Powder, and Fuze Powder. Sodium nitrate is used in place of potassium nitrate in U.S.A. for cheap black powder (Thorpe, IV, 458).

Gunpowders are used mainly for industrial and sporting purposes. For military use, however, smokeless powders, introduced towards the close of the nineteenth century, have assumed importance.

Gunpowder causes fouling of weapons followed by corrosion, necessitating frequent cleaning and replacement of weapons. Also, the powder is hygroscopic and special precautions have to be taken to keep it dry; it produces heavy smoke and brilliant flashes, and dry powder is sensitive to friction and heat.

Smokeless powders consist of colloided nitrocellulose (guncotton, or collodion cotton, or both) as such or in admixture with nitroglycerin, stabilizers, flash reducers, restrainers, etc. On ignition they burn on the surface and by varying the form and size of the grains the energy released can be controlled over wide limits to suit the requirements of different weapons. They are manufactured in flake, strip, pellet, or cylindrical forms. Three types of smokeless powders are manufactured: (1) partially colloided single base powder, (2) colloided single base powder, and (3) double base powder. Nitrocellulose is gelatinized by a volatile or non-volatile solvent; acetone is used as solvent for guncotton and a mixture of alcohol and ether for collodion cotton. Centralites (dialkyldiphenylureas) and phenylurethanes are employed as non-volatile gelatinizers. Centralites

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and diphenylamine are used as stabilizers and potassium chloride, potassium bitartrate, and cellulose flour as antishocks.

Partially colloid single base powders or Schultze powders are commonly used in commercial shot gun and blank ammunition. Guncotton and potassium and barium nitrates are mixed mechanically in the presence of water and granulated. A mixture of acetone and alcohol or benzene is sprinkled to gelatinize the outer surface and the grains dried. Mononitrobenzene, dinitrobenzene, and toluene are sometimes incorporated to moderate the action and to assist gelatinization. Partially colloid powders have low density and are more quick burning than military powders.

Colloid single base powders contain nitrocellulose as the principal constituent. Nitrocellulose is dehydrated, mixed with solvent and other ingredients, kneaded into a dough, extruded into threads or blocks, cut, and dried. Colloiding is effected by a mixture of alcohol and ether.

Double base powders contain nitrocellulose and nitroglycerin as principal constituents. A mixture of alcohol and acetone is used as solvent. For formulating compositions in which the nitroglycerin content exceeds 40%, wet nitrocellulose is colloid in admixture with nitroglycerin and other ingredients in heated rolls and cast in sheet form. The sheets are extruded to form large grains. Double base powders are of greater ballistic potential than single base powders and are non-hygroscopic. Cordite belongs to the class of double base smokeless powders.

Ball powder is prepared by suspending partially stabilized nitrocellulose or deteriorated nitrocellulose powder in water and agitating in the presence of stabilizers and solvents; moderants and/or nitroglycerin and a colloid, such as glue, are added. The balls are hardened by distilling off the solvent. Ball powder is used in military small-arms ammunition, small-calibre gun, and sporting ammunition (*Rep. Progr. appl. Chem.*, 1950, 35, 292).

THE INDIAN INDUSTRY

The history of the manufacture of explosives in India goes back to 1670 when the East India Company put up a plant in Bombay for the manufacture of gunpowder. The factory was moved to Kirkee in 1870. The manufacture of percussion caps was started in 1845 in the gunpowder factory in Bombay, and in Madras and Dum Dum near Calcutta. The factories at Madras and Dum Dum were closed down later. The manufacture of cordite was started at Aravankadu in Nilgiri hills (Madras State) in 1903. This factory now produces guncotton, nitroglycerin, and cordite. The *High Explosives Factory* at Kirkee produces ammonium nitrate, T.N.T., D.N.T., Amatols, lead

azide, lead styphnate, A.S.A. mixture (consisting of lead azide and lead styphnate), and tetryl (or Composition Exploding, C.E.). Various new types of explosives, such as plastic explosives, aluminized explosives, incendiary compositions and gels, were manufactured at Kirkee during World War II. Gunpowder and safety fuzes are manufactured by private concerns.

Initiatories—Mercuric fulminate is produced by the interaction of alcohol and a solution of mercury in excess of nitric acid. The distillate driven off by the heat of reaction is recovered and the fulminate is precipitated. The precipitate is filtered and washed (Thorpe, IV, 536).

Lead azide is prepared by treating sodium azide (prepared by treating sodium amide with nitrous oxide) with lead acetate or nitrate.

Lead styphnate is prepared by dissolving trinitroresorcinol and sodium carbonate in water, then adding a boiling solution of lead nitrate, and acidifying with acetic acid. On stirring, the lead salt is deposited, which is filtered, washed with alcohol, and dried in air (Thorpe, IV, 542).

Ammonium nitrate (cf. With India, Pt. I, 94)—Ammonium nitrate is produced from gaseous ammonia and liquid nitric acid, utilizing the heat of reaction for concentrating the solution of ammonium nitrate obtained. It is manufactured at the *High Explosives Factory*, Kirkee, for the production of Amatols.

T.N.T.—Trinitrotoluene is made by the nitration of toluene with mixed acid in cast iron or steel nitrators by batch or continuous processes. Toluene of a high degree of purity is required for the manufacture of T.N.T.

In the *High Explosives Factory*, Kirkee, toluene is converted to mononitrotoluene by a batch process and further nitrated to T.N.T. in a continuous plant. The plant consists of a series of cast iron pots, one of each pair being provided with a stirrer and the other acting as a settling vessel. The nitrated body passes from the settling vessel to the next agitator, the acids moving countercurrent so that they encounter increasingly stronger acids as they move from one agitator to the other. The temperature is not allowed to exceed 100°. T.N.T. emerges from one end and the spent acid from the other. The nitrated product is agitated with a 5% solution of sodium sulphite for eliminating the products of side reactions, washed with warm water, dried by warm air, flaked, and packed in paper-lined wooden containers.

D.N.T.—Dinitrotoluene required for the production of improved cordite is produced at Kirkee. The plant used in the production of T.N.T. is used also for the production of dinitrotoluene. The product is bled from the plant at about one-third of the way up the series of nitrators. The crude D.N.T. thus obtained is purified by washing with

water and sulphite solution, centrifuged to remove mononitrotoluene, and finally cast into slabs.

In the batch process, mononitrotoluene is nitrated by mixed acid containing : sulphuric acid, 62; nitric acid, 21; and water, 17%. The addition of the mixed acid is regulated so that the temperature of the mixture does not exceed 60°. After the addition of acid, the charge is heated to 90° and maintained at that temperature until a test sample shows a setting point of 54–55°. The waste acid is removed and dinitrotoluene 'pelleted' by impinging a stream of cold water on the molten material. The product is thoroughly washed, remelted, filtered through felt, and dried (Thorpe, IV, 466).

Amatols—Amatols are manufactured in the *High Explosives Factory*, Kirkee, by adding calculated quantities of hot ammonium nitrate to molten T.N.T. The resulting mixture is stirred until the desired fluidity is obtained and poured directly into shells or bombs.

Tetryl—Tetryl is manufactured from pure dimethylaniline by treatment with mixed sulphuric and nitric acids in a multi-stage nitration plant.

Nitroglycerin—Nitroglycerin is manufactured at Aravankadu (Madras State). Anhydrous glycerol of a high degree of purity (c. 99.9%) and mixed acid containing 50% nitric acid (pure anhydrous) and 50% sulphuric acid (pure and containing not less than 96% sulphuric acid by weight) are required. The nitrators are cooled by internal cooling coils carrying brine at –5° and the temperature of nitration is maintained below 15°. The nitration is conducted for 60–90 minutes and the mixture allowed to flow into separating and settling tanks where the lighter nitroglycerin forms a top layer over the spent acid. Nitroglycerin is separated, washed twice with warm water in wash tanks, then with 1% solution of sodium carbonate, and again with warm water to free it from alkali.

Guncotton—Guncotton is manufactured at Aravankadu from cotton waste obtained from spinning mills. Cotton is degreased, kier-boiled with a weak solution of soda ash and caustic soda, bleached, washed, neutralized with sulphuric acid, again washed, and dried. Mixed acid is made up from fortifying acid and spent acid, brought to the proper temperature, and a weighed quantity of cleaned cotton is added. The nitration is conducted under controlled conditions. The nitrator charge is dropped into a centrifuge and the spent acid separated. The nitrated cotton is drowned in an immersion tank provided with running water, and finally washed by boiling with water in a beater.

Cordite—Guncotton is dried by hot air to a moisture content of 0.5%, cooled, weighed out into rubber-lined canvas bags, and mixed with the requisite quantity of nitroglycerin. The bags

are taken to the mixing house where the contents are mixed on a lead table with $\frac{1}{2}$ in. perforations, the 'cordite paste' falling into bags kept below to receive it. The paste is kneaded with acetone for c. $3\frac{1}{2}$ hr. in a closed system to prevent acetone evaporation. Mineral jelly is then introduced and the kneading continued for another $3\frac{1}{2}$ hr. keeping the temperature under 40°. The resulting cordite dough is squirted or pressed. Cords of smaller size are wound on reels; those of larger size are cut into required lengths, and dried at 40° for 2–15 days. The acetone obtained during drying is recovered by absorption in sodium bisulphite solution and distillation after sodium carbonate addition (Thorpe, III, 362).

In addition to the older type of cordite W.M., the Aravankadu factory manufactures cordite A.N. (containing nitrocotton, nitroglycerin, D.N.T., carbamate, mineral jelly, potassium nitrate) which is less erosive and gives less flash.

Gunpowder—Gunpowder is produced in India on a sufficiently large scale to meet the major part of the country's requirements. The industry is in the hands of hereditary artisans and the methods of manufacture are somewhat primitive. Production units are scattered all over the country.

Charcoal is prepared by burning selected woods in the open. It is broken up to the required fineness and sieved to remove coarse particles. Sulphur is obtained by import in powder form. The two ingredients are mixed together by hand roughly in the proportion of 15:10. Nitre, which is obtained in a semi-purified state (70–90%), is partially purified by dissolving in the minimum quantity of water and heating in an open pan. The scum formed is removed. The solution is cooled and the mixture of charcoal and sulphur added to the nitre pan and mixed. The mixture is dried in the sun and stored. For finishing, the crude mixture is pounded in wooden mortars, powdering being continued or repeated until the desired 'density' is secured. The product is corned by rubbing over a mat or gunny bag and dried in the sun. A small quantity of water is added during pounding if the crude mixture is dry.

The quality of the finished product varies according to the purity and the proportion of raw materials used and the experience of the workers. Every batch is subjected to a blasting trial to determine its efficacy. The product has poor keeping quality. Due to the presence of hygroscopic impurities it absorbs moisture from the atmosphere. Drying of damp powder does not give a satisfactory product as drying takes place on the surface and causes the 'salting out' of nitre.

The total quantity of gunpowder produced in India is not known. Based on the quantity of

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sulphur allotted to the industry, the annual production is estimated at 2,500 tons valued at Rs. 30,00,000 (Information from the Chief Inspector of Explosives, Govt. of India).

L.O.X.—The use of L.O.X. for blasting has not been very popular on account of the reluctance of miners to adopt new explosives. Both cartridges and liquid oxygen are produced in India and separately supplied by the *Indian Oxygen & Acetylene Co. Ltd.* Cartridges are transported in ordinary packing cases. Liquid oxygen is transported in spherical vacuum containers of 15-25 litre capacity to the site by rail or other available conveyance. Soaking is done in cylindrical vacuum vessels also supplied by the *Indian Oxygen & Acetylene Co. Ltd.* A number of cartridges are arranged in the soaking vessel into which liquid oxygen is poured (Information from the *Indian Oxygen & Acetylene Co. Ltd.*, Calcutta).

Approximately 60,000 litres of liquid oxygen are annually consumed for blasting purposes. L.O.X.

is used for blasting granite, limestone, and magnesite; coal quarrying; railroad cutting; bridge demolition; etc.

Safety fuze—Safety fuze is manufactured on a small scale in India; the bulk of the requirements is imported. Safety fuze consists of a train of fine-grained gunpowder enclosed in braided tube of jute rendered impervious to water by an outer coating of tar or other material. Two factories have been recently started in India for safety fuze manufacture. Only one of them is working at present. The raw materials, jute, gunpowder, and tar, are readily available and the existing annual demand is valued at Rs. 19 lakhs approximately. The output from this factory meets only a fraction of the country's requirements (Information from the Chief Inspector of Explosives, Govt. of India).

Trade—Considerable amounts of explosives are imported into India. Tables 5 and 6 give the imports of gunpowder and other explosives into India.

TABLE 5—IMPORTS OF GUNPOWDER AND SMOKELESS POWDERS
(Qty in 1,000 lb. and val. in thousand Rs.)

| | Black | | Smokeless | | Others | |
|-----------------------|-------|-------|-----------|-------|--------|--------|
| | Qty | Val. | Qty | Val. | Qty | Val. |
| 1934/35-1938/39 (av.) | 59.6 | 35.44 | 11.9 | 17.22 | 22.0 | 9.88 |
| 1939/40-1943/44 (av.) | 14.41 | 12.86 | 2.1 | 9.55 | 38.1 | 25.43 |
| 1944-45 | 18.8 | 21.28 | 3.6 | 9.71 | 8.8 | 8.69 |
| 1945-46 | 18.5 | 25.84 | 11.3 | 26.11 | 24.6 | 20.35 |
| 1946-47 | 22.6 | 41.00 | 7.5 | 14.36 | 109.1 | 97.72 |
| 1947-48 | 7.7 | 14.08 | 4.9 | 18.68 | 66.7 | 59.98 |
| 1948-49 | 16.9 | 25.25 | 7.0 | 20.50 | 62.0 | 61.78 |
| 1949-50 | 11.7 | 19.00 | 1.3 | 5.99 | 13.8 | 13.17 |
| 1950-51 | 3.6 | 8.50 | .. | .. | 259.3 | 209.32 |
| 1951-52 | 9.7 | 24.12 | 4.2 | 14.47 | 136.9 | 149.67 |
| 1952-53 | 18.4 | 34.82 | 1.3 | 6.72 | 178.9 | 262.78 |

TABLE 6—IMPORTS OF EXPLOSIVES OTHER THAN GUNPOWDER & SMOKELESS POWDERS
(Qty in 1,000 lb. and val. in thousand Rs.)

| | Blasting gelatin | | Gelatin dynamite | | Other nitro-compound explosives | | Detonators | | Blasting fuze, etc. | |
|-----------------------|------------------|----------|------------------|----------|---------------------------------|----------|------------|----------|---------------------|----------|
| | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. | Qty | Val. |
| 1934/35-1938/39 (av.) | 519.0 | 451.39 | 1,288.9 | 906.82 | 275.3 | 167.39 | 7,048.8 | 187.56 | 1,011.0 | 476.41 |
| 1939/40 | 47.8 | 40.09 | 1,403.2 | 1,095.74 | 529.5 | 362.28 | 8,182.0 | 198.29 | 1,301.9 | 1,272.66 |
| 1943/44 (av.) | .. | .. | 2,024.3 | 1,529.79 | 253.5 | 152.07 | 10,857.5 | 348.14 | 483.1 | 589.80 |
| 1944-45 | 10.0 | 11.52 | 2,167.5 | 1,781.06 | 420.0 | 334.67 | 6,837.5 | 375.40 | 593.8 | 846.33 |
| 1945-46 | 96.2 | 111.96 | 3,362.2 | 2,784.45 | 400.0 | 344.12 | 12,488.0 | 662.01 | 1,500.6 | 1,932.05 |
| 1946-47 | 106.3 | 123.26 | 3,278.0 | 2,854.87 | 499.7 | 452.35 | 6,832.1 | 669.37 | 1,644.1 | 2,262.97 |
| 1947-48 | 89.4 | 107.81 | 3,970.7 | 3,557.37 | 1,017.6 | 932.68 | 15,564.6 | 895.85 | 1,610.9 | 1,922.81 |
| 1948-49 | 792.2 | 782.82 | 2,084.7 | 2,048.31 | 650.0 | 602.07 | 6,125.6 | 450.16 | 1,227.3 | 1,723.36 |
| 1949-50 | 759.4 | 827.99 | 4,133.1 | 4,142.92 | 1,361.0 | 1,315.81 | 21,023.1 | 1,322.10 | 2,724.8 | 3,209.08 |
| 1950-51 | 4,138.6 | 4,860.42 | 1,264.3 | 1,472.58 | 1,305.5 | 1,550.64 | 18,037.7 | 1,390.82 | 2,301.0 | 4,939.03 |
| 1951-52 | 5,851.1 | 7,718.33 | 2.1 | 4.67 | 1,340.3 | 1,836.39 | 22,565.8 | 2,095.99 | 2,884.2 | 7,680.37 |
| 1952-53 | | | | | | | | | | |

TABLE 7—IMPORTS OF EXPLOSIVES FROM U.K.

| | Qty | | | | Val. (£) | | | |
|------------------------------|-----------|----------|-----------|-----------|----------|---------|---------|---------|
| | 1945 | 1946 | 1947 | 1948 | 1945 | 1946 | 1947 | 1948 |
| Sporting ammunition | | | | | | | | |
| Loaded cartridges | | | | | | | | |
| thousands | 5,017 | 12,749 | .. | .. | 36,977 | 110,040 | .. | .. |
| cwt. | 4,350 | 10,538 | | | | | | |
| Fuzes & blasting accessories | | | | | | | | |
| Safety fuze coils of | | | | | | | | |
| 24 ft. | 1,444,042 | 4,96,792 | 4,363,908 | 2,938,550 | 34,412 | 124,017 | 122,177 | 86,513 |
| cwt. | 3,357 | 11,680 | 10,458 | 7,499 | | | | |
| Other fuzes, tubes, primers, | | | | | | | | |
| etc. (cwt.) | 53 | 100 | 18 | 174 | 3,391 | 3,000 | .. | .. |
| Other accessories (includ- | | | | | | | | |
| ing detonators, cables, | | | | | | | | |
| etc.) (cwt.) | 490 | 621 | 1,129 | 1,204 | 20,888 | 42,157 | 58,184 | 71,470 |
| High explosives | | | | | | | | |
| Blasting powder (cwt.) | 1,096 | 796 | 1,295 | 1,163 | 6,175 | 4,990 | 7,462 | 6,923 |
| Gelatinous (cwt.) | 6,907 | 30,961 | 44,301 | 53,466 | 47,111 | 176,012 | 249,160 | 361,636 |
| Rockets & other pyro- | | | | | | | | |
| technic products (cwt.) | .. | .. | .. | .. | 2,927 | 4,291 | 2,144 | 6,668 |
| Explosives, not elsewhere | | | | | | | | |
| specified | .. | .. | .. | .. | .. | 13,820 | 8,918 | 49,705 |
| Ammunition, not elsewhere | | | | | | | | |
| specified | .. | .. | .. | .. | .. | 1,509 | 1,916 | 5,080 |

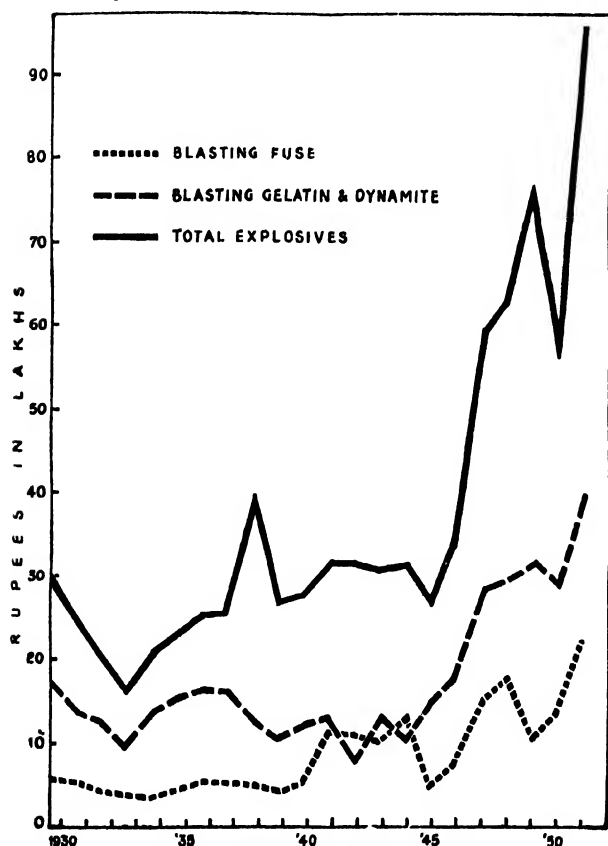


FIG. 94—IMPORTS OF EXPLOSIVES

TABLE 8—ANNUAL CONSUMPTION OF EXPLOSIVES IN KOLAR GOLD FIELDS*

| | |
|-------------------------------------|-----------|
| Ammon. gelatin | |
| (3" × 1" × 4", 1" × 8", 1½") lb. | 552,550 |
| Ammon. gelignite 1" (lb.) | 40,000 |
| Blasting gelatin (lb.) | 12,500 |
| Sextuple detonators (no.) | 1,489,500 |
| D.C.T. fuze No. 6 (coils) | 155,100 |
| do. (reels) | 800 |
| Electric safety fuze lighters (no.) | 2,500 |
| Multiple fuze igniters (no.) | 1,500 |

* Information from John Taylor & Sons (India) Ltd.

TABLE 9—CONSUMPTION OF EXPLOSIVES IN COAL MINES*
(Qty in lb.)

| | 1945 | 1946 |
|------------------|-----------|-----------|
| Ajax | 340,474 | 277,752 |
| Burrowite | .. | .. |
| Gelatin | 19,293 | .. |
| Gelignite | 647,298 | 1,825,900 |
| Monobel | 109 | .. |
| Stonobel | 351 | .. |
| Liquid oxygen | 62,091 | 107,640 |
| Polar Ajax | .. | 825,690 |
| Polar Viking | .. | 51 |
| Gunpowder | 4,970,176 | 4,686,300 |
| Detonators (no.) | 2,276,774 | 4,432,056 |

* Ann. Rep. of the Chief Inspector of Mines in India for the year ending 31 Dec. 1945, 1947, 10, 106; Ann. Rep. of the Chief Inspector of Mines in India for the year ending 31 Dec. 1948, 1950, 14, 121

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TABLE 10—CONSUMPTION OF EXPLOSIVES IN OTHER MINES*
(Qty in lb.)

| | | Gelatin | | Gelignite | | Gunpowder | | Detonators | |
|-----------|-------|---------|--------|-----------|---------|-----------|---------|------------|-----------|
| | | 1945 | 1948 | 1945 | 1948 | 1945 | 1948 | 1945 | 1948 |
| Mica | mines | .. | 31,755 | 339,056 | 266,629 | 8,099 | 8,506 | 486,182 | 2,135,479 |
| Manganese | " | 248 | 10,144 | 52,102 | 75,669 | 46,086 | 51,286 | 263,376 | 413,788 |
| Limestone | " | .. | .. | 17,239 | 19,331 | 433,110 | 307,245 | 24,261 | 25,152 |
| Stone | " | .. | .. | 7,096 | 3,769 | 117,760 | 35,889 | 21,932 | 4,197 |
| Other | " | 59 | 374 | 372,818 | 455,529 | 337,787 | 258,558 | 622,277 | 671,374 |

* *Ann. Rep. of the Chief Inspector of Mines in India for the year ending 31 Dec. 1945, 1947, 10, 106; Ann. Rep. of the Chief Inspector of Mines in India for the year ending 31 Dec. 1948, 1950, 14, 121*

Table 7 gives the imports of explosives from U.K. Table 8 gives the approximate annual consumption of explosives in the Kolar Gold Fields. Table 9 gives the consumption of explosives in coal mines. Table 10 gives the consumption of explosives in other mines.

An agreement has recently been reached between the Government of India and the *Imperial Chemical Industries, Ltd.*, London, to establish a new company to manufacture India's requirements of commercial blasting high explosives. The company will be known as *Indian*

Explosives Ltd. and will have an authorized capital of Rs. 400 lakhs of which half will be used initially. Of the initial capital, the Government of India will subscribe 20% and the rest will be subscribed by the *I.C.I. Ltd.* The balance of the capital required will be met by loans. The factory will be located close to the Bihar coal-fields so as to give the best possible service to the coal mining industry which is the principal consumer of industrial explosives in India (*Indian Tr. J.*, 1953, 186, 556).

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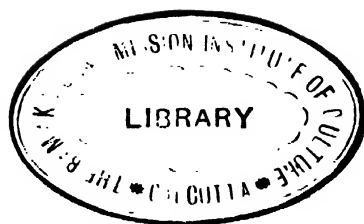
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